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THE PRACTICAL BRASS AND IRON FOUNDER'S GUIDE:

A TREATISE

ON

BRASS FOUNDING, MOULDING, THE METALS AND THEIR ALLOYS, ETC.

BY JAMES LARKIN,

LATE CONDUCTOR OF THE BRASS FOUNDRY DEPARTMENT IN THE PENN WORKS, PHILADELPHIA.

A NEW, REVISED AND GREATLY ENLARGED EDITION.

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PREFACE TO THE REVISED EDITION.

As shown by the constant demand for it, THE PRACTICAL BRASS AND IRON FOUNDER'S GUIDE still maintains the popularity and reputation it has enjoyed for so many years.

The issue of a new edition having become necessary, a large amouut of new and important matter has been added, in order to bring the work up to modern times. Some portions of the original edition being out of date have been eliminated, whilst in others a few alterations have been made. However, in making these alterations as well as the additions, the aim of the author—to prepare a handy book for the use of the practical workman—has been constantly kept in view.

The book has also been provided with a copious table of contents and a very full index, which will add further value by rendering any subject in it easy and prompt of reference.

In its enlarged and improved shape, it is hoped

that the work will fully maintain its claim to the favor it has so long enjoyed as a full and intelligible guide in the workshop.

Philadelphia, June 16, 1892.

PREFACE TO THE FIRST EDITION.

THE world at present groans under a load of new publications on every branch of *science* and *art;* with which no former period of our literary annals can for a moment be compared.

The most assiduous students, unable to peruse a thousandth part of the works which are daily soliciting their attention, are quite perplexed and distressed about what to choose and what to reject.

This I have frequently found to be the case with myself, and while debating the question in my own mind, have lost, in doubt and uneasiness, the time I meant to set apart for practical manipulation.

Impressed, therefore, with the unspeakable disadvantages that result from the circumstances just stated, and anxious to save others, in some degree, from that unpleasant dilemma in which I have myself been so often placed, I have resolved on the present publication, which I hope will to a very great extent accomplish the useful object I have in view.

With what judgment, however, the design has been

formed, and with what skill it has been executed, it becomes not me to determine—that question, to the result of which I am deeply alive, remains now with a higher tribunal.

During the last fifteen years I have, from time to time, contributed papers to well known mechanical and philosophical publications, on subjects herein discussed. These I have carefully revised for the present work, and have added much information gleaned in the field of experience, and from the arcana of science.

I would add in conclusion, that I have been practically employed in the business for thirty-four years, having conducted the work, in all its branches, at Messieurs Sandford et Varreles, Rue de Rochecourt, one of the largest ateliers in Paris, as well as at the British government works, steam-engine and ship-building yard, Woolwich, London, for the last eleven years—so that the reader may relieve himself of all doubt and difficulty in the matter.

JAMES LARKIN.

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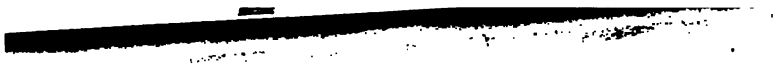

BRASS AND IRON FOUNDER'S GUIDE.

ON THE PROPERTIES OF THE METALS.

THE metals constitute by far the most numerous class of undecompounded bodies in chemical arrangements. They are, in general, readily distinguished from other substances, by characters which every one recognises; but to an ordinary observer they do not appear to differ essentially from one another; they seem rather to owe their differences of colour, and other physical properties, to a tinge and character given to them by adventitious circumstances, and perhaps some trifling admixture of other substances. This opinion is natural, and was at one time the prevailing doctrine of the learned.

When chemistry began to be developed in the hands of the alchemists—upon whom it has been fashionable to heap ridicule for the extravagances of their notions—it was generally admitted that all

metals were essentially the same; and as gold was reckoned the most precious, it was assumed to be the pure basis of all the other metals. Upon this assumption, the aim of alchemy was direct and rational; its object was to separate the substance, whatever it might be, the presence of which prevented lead and other *base* metals from being gold.

It is hardly necessary to observe that these efforts failed. Accordingly modern chemists, taught by experience to believe the required decomposition impossible, have come to the matter-of-fact conclusion that when metals are of different colours, degrees of hardness, lustre, ductility, fusibility, and so on, that they are of different natures.

Although the metallic character be readily and popularly recognised, it is difficult to define it with accuracy.

With the single exception of quicksilver, the metals are all solid at ordinary atmospheric temperatures; but their most striking property is their lustre, which is so remarkable as to be at once understood by the expression, *metallic lustre.* This property belongs, in a greater or less degree, to every metal: it is the property of strongly reflecting light, and seems connected with a certain state of aggregation of the metallic particles. The same

property is however possessed, at least superficially, in a minor degree, by mica, animal charcoal, silenium, and polished indigo—bodies not at all metallic.

In consequence of the peculiar power of the metals to reflect light, they are no less remarkable for their opacity than their lustre. Thus, silver-leaf, only one hundred-thousandth of an inch in thickness, is perfectly opaque; and leaves of other metals, in general, allow no light to pass through their substance. Yet gold-leaf, of the two hundred-thousandth part of an inch in thickness, would seem, as observed by Sir Isaac Newton, to transmit green rays of light; and it is probable that, could we obtain films of other metals of equal thinness, they would be found to allow certain rays to pass through them. The fact, as observed with gold, has however been ascribed to the porosity of the metal, the rays transmitted passing through an infinite number of minute fissures in the thin leaf. This, it must be admitted, is quite compatible with perfect opacity of the substance of the metal; the leaf, like a piece of wire gauze, allowing the light to pass only through its interstices, and not through the solid metal itself, which may be perfectly impervious to all luminous rays.

The polished metals are imperfect radiators and receivers of heat, but they are excellent reflectors, both of light and heat: hence their peculiar fitness for the construction of mirrors. They are also, in general, excellent conductors of heat, and most of them also of electricity, though probably not all. The greater number of them are susceptible of assuming the crystalline form. With several of them this may be effected by fusion and slow cooling. Thus, by suffering the melted metal in a crucible slowly to concrete externally, and then perforating the solid crust, and pouring out the liquid interior, the cavity so formed will be found lined with crystals.

When a metal is precipitated by another, it is often deposited in a crystalline state. Thus, if a little mercury be thrown into a solution of nitrate of silver (lunar caustic), the silver is precipitated in beautiful crystals. The same phenomenon occurs, when a bit of zinc is suspended in a salt of lead. In like manner, if a stick of phosphorus be immersed in a silver solution, it becomes incrusted with beautiful metallic crystals, which after some time perfectly encase the phosphorus. Gold is also sometimes deposited in crystals from its ether solutions; and during the decomposition of several of the

metallic solutions, by galvanic electricity, especially when low powers are employed, beautiful metallic crystals are often obtained. This is readily verified with solutions of copper and silver salts.

The metals possess, in different degrees, a peculiar tenacity, which, in its greatest perfection, renders them *malleable* and *ductile*—that is, capable of being extended under the hammer, and drawn into wire—properties which belong to no other species of matter. Thus, gold and silver may be beaten into leaves almost inconceivably thin; copper, tin, platinum, and lead, possess the same property, but less perfectly; others are entirely destitute of it, as arsenic, antimony, and cobalt. These last can indeed be readily reduced to fine powder, and hence they are distinguished as brittle metals.

Those metals which are malleable are also ductile; these properties are analogous, but do not appear to bear a uniform relation to each other, among the metals possessing them. Gold and silver are, however, the most ductile, as they are the most malleable. Thus, a grain of gold may be extended by hammering, so as to cover fifty-two square inches of surface, or it may be drawn into 500 feet of wire. and by enveloping it in silver, it may be extended to 700 feet. In like manner, platinum, which is in-

ferior to copper and tin in malleability, has been drawn into wire not more than the $\frac{1}{30000}$th of an inch diameter—a degree of fineness, which, except under certain circumstances of illumination, is invisible. Iron may be drawn into wire as fine as the human hair; copper is less ductile, and zinc, tin, and lead, can be drawn into wire, but considerably less fine. The brittle metals, as might be supposed, do not draw.

The following table shows the order which the metals bear to one another, in respect to these properties:—

A TABLE SHOWING THE ORDER WHICH THE METALS BEAR TO ONE ANOTHER IN RESPECT TO THEIR PROPERTIES:—

Order of Malleability.	Order of Ductility.	Order of Tenacity.	Order of Brittleness.
Gold,	Gold,	Iron . . 1000	**Antimony,**
Silver,	Silver,	Copper 550	Arsenic,
Copper,	Platinum,	Platinum 494	Bismuth,
Tin,	Iron,	Silver . . 349	Cerium,
Cadmium,	Copper,	Gold . . 273	Chromium,
Platinum,	Zinc,	Zinc . 199	Cobalt,
Lead,	Tin,	Tin . . . 63	Columbium,
Zinc,	Lead,	Lead . . 50	Manganese,
Iron,	Nickel,		Molybdenum,
Nickel,	Palladium,	Iron wire 1-tenth in. diameter is capable of sustaining 500lbs. avoirdupois.	Tellurium,
Palladium,	Cadmium,		Titanium,
Potassium,			Tungsten,
Sodium,			Uranium,
Solid mercury,			**Rhodium.**

Few of the metals when pure are very hard, and some are so soft as to yield to the nail. The following table of hardness is given from the experiments of M. Dumas:—

Titanium, Tungsten, Manganese,	are harder than steel.
Platinum, Palladium, Copper, Gold, Silver, Tellurium, Bismuth, Cadmium, Tin,	are scratched by calc-spar.
Chromium, Rhodium,	scratch glass.
Nickel, Cobalt, Iron, Antimony, Zinc,	are scratched by glass.
Lead yields to the nail.	
Potassium, Sodium,	are soft as wax at 60°.

Mercury is liquid above minus 39°.

In respect to *fusibility*—that is, the capability of being melted by heat—the metals differ from each other as widely as in any other respect. Thus, mercury requires to be cooled down to minus 39° before it becomes solid, whereas the melting point of platinum is somewhere beyond 3280°. Potassium melts at 140°, and sodium at 190°. Tin becomes liquid at 444°, bismuth at 500°, lead at 600°, zinc at 770°, and antimony at 800°. Silver, gold, and copper, require a bright cherry-red heat to melt them (about 2000°); cast iron, nickel, and cobalt, a white heat (about 2800°); and manganese, and malleable iron, the highest heat of a smith's forge (about 3000°). The highest temperatures of our furnaces are only sufficient to agglutinate very imperfectly the metals molybdenum, uranium, tungsten, and chromium; and titanium, cerium, osmium, iridium, rhodium, platinum, and columbium, require the intense heat of the oxy-hydrogen blow-pipe, or that of voltaic electricity, to fuse them. Some of the metals, when exposed to heat, not only melt, but, obeying the general law of liquids, boil and evaporate when the heat is sufficiently high. Thus, mercury, zinc, cadmium, bismuth, tellurium, and antimony, boil and evaporate at a red heat; and, in a vacuum, mercury is known to evaporate at ordinary atmospheric tem

peratures (above 50°); silver and lead require a high heat to vaporize them; tin a still higher heat; and gold will only evaporate slowly under the most intense heat that can be applied. Several of the other metals, as iron and nickel, cannot be made to evaporate in the most intense heat with which we are acquainted. Arsenic, on the other hand, evaporates without melting.

There are several of the metals which emit a peculiar odour, especially when rubbed, or have their temperature slightly raised. This is particularly the case with copper, iron, and tin. The vapour of others is very remarkable. The arsenic vapour has the smell of garlic; that of tellurium smells like horseradish; and osmium takes its name from the smell of its vapour (osme, odour). Some of the metals have also a peculiar taste when applied to the tongue, which has been ascribed to their electrical condition; but it must be remarked that many of the most oxidable metals are entirely destitute both of *taste* and *odour*.

A high specific gravity was reckoned one of the most marked characteristics of the metals, till the discovery of the metallic basis of the alkalies by Sir Humphrey Davy. So intimately indeed was the metallic lustre associated in the mind with great

weight, that when a piece of potassium was put, for the first time, into the hand of an eminent teacher of chemistry, in admiring its perfect metallic character, he poised it upon the finger, and exclaimed, "How heavy!" and the prejudice was only removed by seeing it float upon water. The list of metals, however, includes the densest forms of matter with which we are acquainted; and, although great weight cannot be regarded as a universal property, we have few examples in which the density is less than the density of water. These examples comprehend only potassium and sodium; all other metals are of greater specific gravity, up to platinum, which is twenty-one times the weight of an equal bulk of water.

The degrees of facility with which the metals combine with oxygen differ widely. Some, by mere exposure to the atmosphere, absorb its oxygen with great rapidity: such is the case with potassium and sodium: others absorb it more slowly, as manganese, iron, and arsenic; and lead and copper still more slowly. Others, again, do not oxidate by exposure to air, unless at a high temperature; this is the case with tin, zinc, mercury, antimony, bismuth, and cobalt, which absorb the oxygen readily when in a

state of fusion. Others, again, do not oxidate by exposure to air and heat, or by immersion in water, as gold and platinum; the same is nearly true of nickel and silver. The tendency of the metals to combine with oxygen appears, however, to be greatly influenced by their mechanical condition; for some of them, which are only slowly oxidized by exposure to air and heat, are rapidly acted upon when in very fine mechanical division, even at common temperatures.

In combining with oxygen under heat, some of the metals burn with great splendour: this is exemplified in copper, zinc, tin, and bismuth. Iron filings, when thrown even into the flame of a candle, and very fine iron wire, when held in the external part of the flame, take fire and throw off beautiful scintillations. Antimony burns at a white heat, and tellurium burns before the flame of the blow-pipe. In short, at intense heats most of the metals may be burned, and, if placed in the flame of the oxy-hydrogen blow-pipe, they deflagrate with intense brilliancy and great facility.

On the other hand, *potassium* burns by contact with a piece of *ice*, with as much intensity as others do in the oxy-hydrogen flame.

The metals, by combination with oxygen, lose their metallic characters, and form an important series of definite compounds known as the *metallic oxides*. These have very different characters and properties; even the same metal not unfrequently affords oxides which differ from each other widely in properties and appearance. Thus fifty parts of mercury, combining with one part of oxygen, produces a black oxide, and with two parts of oxygen, the oxide is red and highly poisonous. Many of the metals thus afford more than one oxide; and it is to be observed, that when the same metal unites in more than one proportion with oxygen, the oxygen in the second and higher oxides bears a definite arithmetical relation to the first; and when two oxides are thus formed, that having the minimum of oxygen is termed the protoxide, and that with the maximum of oxygen the peroxide. This law of definite proportions will be explained hereafter.

Among the combinations of metals with oxygen, some are soluble in water and alkaline, such as the *fixed alkalies*, soda, potash, and lithia, and the *alkaline earths;* others are soluble and sour, forming the *metallic acids*. Some are insoluble in water, and have neither taste nor smell; and many when

taken into the stomach act as poisons. Thus, oxide of arsenic is a notorious and virulent poison; oxide of copper is less virulent than arsenic; oxide of lead is a painful poison; oxide of nickel is also destructive of life; and the peroxide of mercury, unless in small quantities, is likewise poisonous.

ON METALLIC ALLOYS.

THE metals, for the most part, may be combined with each other, forming a most important class of compounds, known as the *metallic alloys*. Many of these are more useful than the metals of which they are composed, and possess properties a good deal different from their elements. One of the best known and most serviceable of all the alloys is brass, a compound of zinc and copper: it is harder, more easily melted, more close in the texture, better coloured, and less liable to tarnish than copper; it is less brittle, and in every way more valuable than zinc. Pinchbeck is composed of the same ingredients as brass, but in different proportions, the zinc predominating. Copper and tin are two very soft and flexible metals, which, being fused together, form the alloy known as bell-metal, which is harder than iron, very brittle, and very sonorous. The same materials, in different proportions, form speculum metal, and the kind of ordnance improperly called brass cannon. Pewter is composed of tin and lead, sometimes with the addition of zinc, copper, or bismuth.

Plates upon which music is stamped are composed of tin and antimony; and printing types are formed of an alloy of lead and antimony, with a slight addition of bismuth. Tin-foil is an alloy of tin and lead; and plumbers' solder is composed of the same metals. Fusible metal is a compound of bismuth, lead, and tin, with sometimes a little mercury.

An *amalgam* of zinc and mercury is used for exciting electric machines, and that of mercury and tin is the compound employed for *silvering* looking-glasses. Gold coin is an alloy of gold and copper, in the proportion of 11 to 1; and jewellers' gold is an alloy of the same metals in the proportion of 3 of gold to 1 of copper. Green gold has silver instead of copper. Silver coin, in like manner, is an alloy of silver and copper in the proportion of 37 to 3. These *alloys* of gold and silver are harder, and consequently less liable to wear than the pure metals.

It is worthy of remark, that in the formation of alloys, the metals in the act of combination generally evolve heat. For instance, when platinum and tin-foil are fused together, there is the most vivid ignition; and when zinc and copper are suddenly mixed, in the proportion to form brass, the increase of heat is such as to vaporize part of the metal.

The alloys are formed by various processes, depending upon the nature of the metals employed. Most of them are prepared by simply fusing the two metals together; but if there be a considerable difference in their specific gravities, the heavier very generally subsides, and the lower part of the mass thus differs in composition from the upper. This may be in a great measure prevented by agitating the alloy till it solidifies, but this is not always convenient. Thus, in stereotype plates which are cast vertically, the upper side usually contains more antimony than the other. The same is observed when an alloy of gold and copper is cast into bars; the mould being placed perpendicularly, the upper part of the bar contains more copper than the lower. Copper and silver evince the same tendency to separate; although they appear readily to combine, it is found extremely difficult to form a bar of their alloy of perfectly uniform composition throughout. Many of the alloys, however, appear to be true chemical compounds; and in some cases the metals unite in definite proportions only.

It is indeed not improbable that wherever metals do form alloys, that the alloys so formed are definite compounds, and that any undue quantity of either metal present, simply mixes mechanically with the

mass. Thus, among the artificial as well as natural alloys, there are many which crystallize; and in some cases, the true compound may be separated from the mere mixture of the superfluous metal by the process of crystallization.

The tendency of the metals to unite with other elements, and with each other, prevents their being often found disseminated in mineral nature, in their pure metallic state.

Some of them do occur so nearly pure as to be called *native metals.* Thus gold is found only slightly alloyed with silver and copper, and platinum occurs as an alloy of iron, palladium, iridium, rhodium, and osmium. Silver, copper, mercury, antimony, bismuth, arsenic, and tellurium, occur both in the native metallic state, although never absolutely pure, and mineralized with other bodies. Lead, tin, zinc, iron, antimony, and several others, are extensively disseminated as sulphurets, that is, combined or mineralized by sulphur.

The combination of a metal with its mineralizing substance, is what we denominate an *ore;* and it is in this state of ore that metals occur, when they are not found native. The ores are exceedingly diversified in appearance; sometimes they possess metallic

lustre; sometimes they appear stony, at other times earthy. In some instances they are crystallized into regular forms, but more commonly they occur in shapeless masses. The ores are chiefly found in *veins*—that is, large fissures of rock, especially the granitic, schistous, and limestone rocks; but sometimes they are found in rounded and detached fragments, disseminated through certain alluvial and diluvial strata of the earth. The extraction of the metal from them is denominated their *reduction*, and implies a laborious series of operations, mechanical and chemical, comprehended under the term *metallurgy*.

The following table contains an enumeration of the metals, and may be useful for reference. The column headed "equivalents," shows the weight which unites with 8 oxygen to form the oxides, and the succeeding column contains the symbols by which the metals are denoted in systematic chemistry.

	Names of Metals.	Authors, and Dates of their Discovery.	Specific Gravity.	Melting Points.	Equ. Hyd. = 1.	Abr. or Sym.
				Fahr.		
1.	Gold (Aurum)	Known to the ancients.	19.25	2016°	200	Au.
2.	Silver (Argentum)		10.47	1873	108	Ag.
3.	Iron (Ferrum)		7.78	*2800?	28	Fe.
4.	Copper (Cuprum)		8.89	1996	64	Cu.
5.	Mercury (Hydrargyrum)		13.56	—39	200	Hg.
6.	Lead (Plumbum)		11.35	612	104	Pb.
7.	Tin (Stannum)		7.29	442	58	Sn.
8.	Antimony (Stibium)	Basil Valentine 1490	6.70	. .	65	Sb.
9.	Bismuth	Agricola . . 1530	9.80	497	72	Bi.
10.	Zinc	Paracelsus? . 1530	7.00	773	32	Z.
11.	Arsenic	Brandt . . 1733	5.88	. .	38	Ar.
12.	Cobalt		8.53	2810?	30	Co.
13.	Platinum	Wood . . . 1741	20.98	oh. bp.†	99	Pl.
14.	Nickel	Cronstedt. . 1751	8.27	2810?	30	Ni.
15.	Manganese	Gahn . . . 1774	6.85	s. f.*	28	Mn.
16.	Tungsten (Wolfram)	D'Elhuiart . 1781	17.60	. .	100	W.
17.	Tellurium	Muller . . . 1782	6.11	620?	32	Te.
18.	Molybdenum	Hielm . . . 1782	7.40	oh bp	48	Mo.
19.	Uranium	Klaproth . . 1789	9.00	oh bp	217	U.
20.	Titanium	Gregor . . . 1791	5.30	oh bp	24	Ti.
21.	Chromium	Vauquelin . 1797	. .	oh bp	28	Cr.
22.	Columbium (Tantalum)	Hatchett . . 1802	. .	oh bp	185	T.
23.	Palladium	Wollaston . 1803	11.50	. .	54	Pd.
24.	Rhodium		. .	oh bp	52	R.
25.	Iridium		. .	oh bp	99	Ir.
26.	Osmium	Tennant . . 1803	. .	oh bp	100	Os.
27.	Cerium	Hisinger . . 1804	. .	. .	48	Ce.
28.	Potassium (Kalium)	Davy . . 1807	0.86	136	40	K.
29.	Sodium (Natronium)		0.97	190	24	Na.
30.	Barium		. .	. .	70	Ba.
31.	Strontium		. .	. .	44	Sr.
32.	Calcium		. .	. .	20	Ca.
33.	Cadmium	Stromeyer . 1818	8.60	442	56	Cd.
34.	Lithium	Arfawedson . 1818	. .	. .	8	L.
35.	Silicium	Berzelius . . 1824	. .	. .	8	S.
36.	Zirconium		. .	. .	33	Zr.
37	Aluminum		. .	. .	14	Al.
38	Glucinum	Wohler . . 1828	. .	. .	18	Gl.
39.	Yttrium		. .	. .	32	Y.
40	Thorium	Berzelius . . 1829	. .	. .	60	Th.
41.	Magnesium	Bussy . . . 1829	. .	. .	13	Mg.
42.	Vanadium	Seftstrom . . 1830	. .	. .	69	V.
43.	Lantanum	Mosander . 1840	. .	. .	?	Ln.

*Smith's forge. †Oxy-hydrogen blowpipe.

ON THE CONDUCTING POWERS OF VARIOUS METALS FOR VOLTAIC ELECTRICITY.

THE researches of Pouillet have thrown much light upon our knowledge of the conducting powers of various bodies for voltaic electricity, and the results he has arrived at enable him to express the relative conducting powers of the different metals by the following numbers:—

Palladium	5791
Silver	5152
Gold	3975
Copper	3838
Platinum	855
Bismuth	384
Brass from	900 to 200
Cast steel from	800 to 500
Iron	600
Mercury	100

The resistance of metals to conduction of electricity has been accurately ascertained by means of the degrees of heat evolved by the passage of a current of equal intensity through different metals;

the heat developed in conducting wires is in proportion to the extent of surface of the positive plate, no matter whether the current emanate from a single cell or a series of cells. The following table shows the degrees of heat evolved by an equal current from different metals, measured by the pressure of expanded air upon a column of alcohol:

Metals.	Heat Evolved.	Resistance.
Silver	6	1
Copper	6	1
Gold	9	1½
Zinc	18	3
Platinum	30	5
Iron	30	5
Tin	36	6
Lead	72	12
Brass	18	3

It is apparent that the conducting powers of the above metals are inversely as these numbers. Silver being a better conductor than lead, in the ratio of 12 to 1.

TABLE OF EXPERIMENTAL RESULTS AS TO SOME OF THE CHEMICAL AND PHYSICAL PROPERTIES OF THE ATOMIC ALLOYS OF COPPER AND ZINC, AND OF COPPER AND TIN. BY R. MALLET, M. R. I. A., ASS. INS. C. E., ETC.

TABLE I.—Showing the Chemical and Physical Properties of the Atomic Alloys of Copper and Zinc.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of Experiment.	Chemical Constitution.	Composition by weight per cent.	Atomic Weight, Hydrogen Being Taken as 1.	Specific Gravity.	Colour.	Fracture.	Ultimate Cohesion, per square Inch in Tons.	Order of Ductility.	Order of Malleability at 60° Fahrenheit.	Order of Hardness, &c.	Order of Fusibility.	Characteristic Properties, in Working, &c.	Relation to Cast-Iron, in presence of a solvent, i.e. Sea Water.
1	C. +	100.00 + 0	31.6	8.667	Tile Red.	E.	24.6	8	1	22	15	Well known.	All these Alloys increase the Corrosion of Cast Iron in Sea Water, when in their presence.
2	10 C. + Z.	90.70 + 9.30	348.3	8.605	Reddish yellow,	1 C. C.	12.1	6	13	21	14		
3	9 C. + Z.	89.80 + 10.20	316.7	8.607	Reddish yellow,	2 F. C.	11.5	4	11	20	13		
4	8 C. + Z.	88.70 + 11.30	285.1	8.633	Reddish yellow,	3 F. C.	12.8	2	10	19	12	Similor, &c. (Several of these are malleable at high temperatures.)	
5	7 C. + Z.	87.70 + 12.30	253.4	8.587	Reddish yellow,	4 F. C.	13.2	9	9	18	11		
6	6 C. + Z.	85.08 + 14.92	221.9	8.591	Yellowish red,	3 F. F.	14.1	5	8	17	10		
7	5 C. + Z.	83.02 + 16.98	190.3	8.415	Yellowish red,	2 F. C.	13.7	11	2	16	9	Bath Metal.	
8	4 C. + Z.	79.65 + 20.35	158.7	8.448	Yellowish red.	1 F. C.	14.7	7	3	15	8	Dutch Brass.	
9	3 C. + Z.	74.58 + 25.42	127.1	8.397	Pale yellow.	F. C.	13.1	10	4	14	7	Rolled Sheet Brass	
10	2 C. + Z.	66.18 + 33.82	95.5	8.299	Full yellow,	1 F. C.	12.5	3	6	13	6	British Brass.	
11	C. + Z.	49.47 + 50.53	63.9	8.230	Full yellow,	2 C. C.	9.2	12	5	12	6	German Brass.	
12	C. + 2 Z.	32.85 + 67.15	96.2	8.283	Deep yellow.	C. C.	19.3	1	7	10	6	Brass, Watchmakers.	
13	8 C. + 17 Z.	31.52 + 68.48	801.9	7.721	Silver white,	1 C.	2.1	0	22	5	5	Very Brittle, (Too hard to file or turn, lustre nearly equal to Speculum Metal.)	
14	8 C. + 18 Z.	30.30 + 69.70	834.2	7.836	Silver white,	2 V. C.	2.2	0	23	6	5	Very Brittle,	
15	8 C. + 19 Z.	29.17 + 70.83	866.5	8.019	Silver gray,	3 C.	0.7	0	21	7	5	Very Brittle,	
16	8 C. + 20 Z.	28.12 + 71.88	898.8	7.603	Ash gray,	3 V.	3.2	0	19	3	5	Brittle,	
17	8 C. + 21 Z.	27.04 + 72.96	931.1	8.058	Silver gray,	2 C.	0.9	0	18	9	5	Brittle,	
18	8 C. + 22 Z.	26.24 + 73.76	963.4	7.882	Silver gray,	1 C.	0.8	0	20	8	5	Very Brittle,	
19	8 C. + 23 Z.	25.39 + 74.61	995.7	7.443	Ash gray,	4 F. C.	5.9	0	15	1	5	Barely Malleable.	All these Alloys decrease the Corrosion of Cast Iron in Sea Water, when in their presence.
20	C. + 3 Z.	24.50 + 75.50	128.5	7.449	Ash gray,	1 F. C.	3.1	0	16	2	4	Brittle.	
21	C. + 4 Z.	19.65 + 80.35	160.8	7.371	Ash gray,	2 F. C.	1.9	0	14	4	3	White Button Metal.	
22	C. + 5 Z.	16.31 + 83.69	193.1	6.605	Very dark gray.	F. C.	1.8	0	17	11	2	Brittle.	
23	+ Z.	0 + 100.00	32.3	6.895	Bluish gray.	T. C.	15.2	13	12	23	1	Brittle, well known.	

TABLE II.—Showing the Chemical and Physical Properties of the Atomic Alloys of Copper and Tin

1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of Experiment.	Chemical Constitution.	Composition by weight per cent.	Atomic Weight, Hydrogen being taken as 1.	Specific Gravity.	Colour.	Fracture.	Ultimate Cohesion, per square inch in Tons.	Order of Ductility.	Order of Malleability at 60° Fahrenheit.	Order of Hardness, &c.	Order of Fusibility.	Characteristic Properties, in Working, &c.	Relation to Cast-Iron, in presence of a solvent, i.e. Sea Water.
1	C. +	100.00 + 0	31.6	8.867	The Red.	E.	24.6	1	2	10	16	Well known.	Every Alloy of C. + T. increases the Corrosive action of Sea Water on Cast Iron, in their presence; the maximum increase is due to Tin.
2	10 C. + T.	84.29 + 15.71	374.9	8.561	Reddish yellow, 1	F.C.	16.1	2	6	8	15	Gun Metal, &c.	
3	9 C. + T.	82.81 + 17.19	345.3	8.162	Reddish yellow, 2	F.C.	15.2	3	7	5	14	Gun Metal, &c.	
4	8 C. + T.	81.10 + 18.90	311.7	8.459	Yellowish red, 2	F.C.	17.7	4	10	4	13	Gun Metal and Bronze.	
5	7 C. + T.	78.97 + 21.03	280.1	8.728	Yellowish red, 1	V.C.	13.6	5	11	3	12	Hard Mill Brasses, &c.	
6	6 C. + T.	72.27 + 27.73	248.5	8.750	Bluish red, 1	V.	9.7	0	12	2	11	Brittle,	All these Alloys found occasionally in Bells, with mixtures of Zinc and Lead.
7	5 C. + T.	72.80 + 27.20	216.9	8.575	Bluish red, 2	C.	4.9	0	13	1	10	Brittle,	
8	4 C. + T.	68.21 + 31.79	185.3	8.400	Ash gray.	C.	0.7	0	14	6	9	Crumbles,	
9	3 C. + T.	61.69 + 38.31	153.7	8.539	Dark gray.	T.C.	0.5	0	16	7	8	Crumbles,	
10	2 C. + T.	51.75 + 48.25	122.1	8.416	Grayish white, 1	V.C.	1.7	0	15	9	7	Brittle,	
11	C. + T.	34.92 + 65.08	90.5	8.056	Whiter still, 2	T.C.	1.4	0	9	11	6	Small Bells, Brittle.	
12	C. + 2 T.	21.15 + 78.85	149.4	7.387	Whiter still, 3	C.C.	3.9	0	8	12	5	" Brittle.	
13	C. + 3 T.	15.17 + 84.83	208.3	7.447	Whiter still, 4	C.C.	3.1	0	5	13	4	Speculum Metal of authors	
14	C. + 4 T.	11.82 + 88.18	267.2	7.472	Whiter still, 5	C.C.	3.1	8	4	14	3	" Files, Tough.	
15	C. + 5 T.	9.68 + 90.32	326.1	7.442	Whiter still, 6	E.	2.5	6	3	15	2	" Files, Soft & Tough.	
16	+ T.	0 + 100.00	58.9	7.291	White, 7	F.	2.7	7	1	16	1	Well known.	

Abbreviations used in column 7th to denote character of Fracture:—F.C. Fine Crystalline, C.C. Coarse Crystalline, T.C. Tabular Crystalline, F.F. Fine Fibrous, C. Conchoidal, V.C. Vitreo-Conchoidal, V. Vitreous, E. Earthy.

The maxima of ductility, malleability, hardness, and fusibility, are = 1.

The numbers in column 6th denote intensity of shade of the same colour.

The atomic weights are those of the hydrogen scale.

The specific gravities were determined by the method indicated in report "On Action of Air and Water on Iron," Trans. Brit. Ass. Vol. vii. p. 283.

The ultimate cohesion was determined on prisms of 0.25 of an inch square, without having been hammered or compressed after being cast. The weights given are those which each prism just sustained for a few seconds before disruption.

The copper used in these alloys was granulated, and of the finest "tough pitch;" the zinc was Mosselman's from Belgium; and the tin "grain tin," from Cornwall. They were alloyed in a peculiar apparatus, to avoid loss by oxidation, and the resulting alloy verified by analysis.

No simple binary alloy of copper and zinc, or of copper and tin, works as pleasantly in turning, planing, or filing, as if combined with a very small proportion of a third fusible metal—generally lead is added to C. + Z., and Zinc to C. + T., as is known to workers in metals.

BEHAVIOR OF METALS AND ALLOYS IN MELTING AND CONGEALING.

THE metals are not all equally suitable for casting, their availability for this purpose being dependent on their behavior in melting, casting and congealing.

The fusibility of the metals and their condition in a melted state have first to be considered. Metals fusing with difficulty (platinum, etc.) and those which are too thickly-fluid in a melted state (white pig-iron) are not, or but seldom used for castings. The average temperatures—melting points—at which the metals liquefy are as follows:

Cast steel	melts at	2507°	F.
Gray pig-iron	"	2327	"
Copper	"	1992	"
Gold	"	1992	"
White pig-iron	"	1967	"
Silver	"	1832	"
Zinc	"	779	"
Lead	"	639	"
Bismuth	"	512.6	"
Tin	"	451.4	"

The melting points of alloys are, as a rule, lower than those of their constituent metals.

With some metals—for instance tin—the transition from a solid to a fluid state takes place suddenly, while others first pass into a pasty state. In the first case the metals are generally more thinly-fluid, which, however, is frequently dependent on foreign admixtures. Phosphorus increases the fluidity, while sulphur decreases it. The fluidity of brass, German silver and bronze is promoted by zinc. Lead has the same effect upon bronze and tin alloys.

The more thinly-fluid the metals are, the more suitable they are for casting, since they fill the moulds well and permit the manufacture of castings with slight cross-sections. Castings must, as a rule, possess an accurately prescribed size. The dimensions of the patterns are always somewhat larger for the following reasons: All metals, when heated, expand, and, hence, after cooling have a smaller volume than in the heated state. Furthermore, a decrease in volume also takes place in the transition from the fluid to the solid state, zinc and cast iron alone forming an exception, they expanding on congealing. But, on the whole, the expansion in congealing is not so great as the decrease in volume in cooling, so that the casting will always be somewhat smaller than the pattern. Only with a few varieties of cast-iron rich in graphite, the contraction in cooling

the rim which is thinnest is cooled off by the walls of the mould and sets immediately. The arms, containing more metal in a mass, cool next and set. The hub, containing the most metal in a mass, cools last and sets, but in doing so, like all the rest of the metal, has a tendency to contract from its moulded size. It is now easy to see that the shrinkage of the hub will have a tendency to separate itself from the arms, or these from the rim, hence the strain upon the rim is of such a nature as to cause it to close together and form a circle of less diameter than is natural. When the piece is broken out the strain relieves itself by drawing the rim together. To overcome as much of the evil of this strain as possible, it is usual to curve the arms, which by straightening somewhat under the influence of the strain, renders them less likely to be broken.

If a piece be broken from a ring no perceptible change of form will take place, the piece can be returned quite readily and will be found to fit; this, however, does not prove that there is no strain present; on the contrary, we will show that there is.

When the ring is first cast, the walls of the mould cool off the inner and outer circumferences immediately, causing them to set, the central core of the metal still remaining hot. In a few moments more it

sets, and in shrinking exerts two influences, one to reduce its own diameter and that of the outer crust to which it is attached and which has already set; and the other to crawl around in the direction of the circumference, whereby, with reference to the outer, there is a tendency to close together; yet, with reference to the inner crust there is a tendency to open outward. Hence if the ring be put in a lathe, and the outer crust removed, the gap will be noticed to close in, increasing in this tendency as we near the centre of the ring with the tool. As we progress toward the inner crust from the centre, an opposite effect will be produced, and the gap will be noticed to open. In a ring of 27 inches diameter, turned till the outer crust was just removed, the ring closed together $\frac{1}{32}$ of an inch in 4 inches.

Cylinders are no more than deep rings, and the strains explained under rings are also present here. The shrinkage strains within hollow, spherical shell castings are similar to those explained under rings, they being no more, in fact, than rings continued about a central axis. In the case of solid globular castings, the heart or central point within will usually be found hollow or porous, owing to the following causes: The walls of the mould cooling off the outer surface, causes it to set immediately; the interior,

cooling from the exterior inward, endeavors to shrink away from the outer crust, which resists its so doing; hence, the interior is kept to a greater diameter than is natural, and, there being but so much metal in the entire mass, the atoms are drawn away from the central point toward all directions to supply the demand made by the metal in shrinking.

The general laws regarding shrinkages are presented by Mr. Alfred E. Watkins as follows: The most metal in a mass always shrinks last; hence, if a casting be composed of irregular thickness it will be liable to be broken by the forces contained within itself. It is, therefore, especially necessary that columns and castings, supporting or resisting great pressures, should be so designed as to prevent this great error. Mouldings on columns are often so badly designed with regard to this matter, that the columns are excessively weak where they should be strongest. As a rule, mouldings should seldom be cast on a column, but rather bolted on. Much of the irregularity of flat castings and those of irregular shapes could be remedied by a proper attention to cooling the castings while in the mould. To be sure this is done to a certain extent, though few moulders know why they do so. They know that by removing the sand from a particular casting it will straighten

in the shrinking. This is but the result of experience, not of thought or any attempt to know why they so act. It is useful to know also that all shrinkage takes place while the casting is changing from a red to a black heat.

ON FOUNDING.

THE general object of *founding* is, to mould iron, copper, tin, zinc, lead, &c., &c., in a melted state into the various forms required for the parts of machines and other constructions.

Wrought iron and steel cannot be properly melted by heat. At high temperatures they drop away and spark off, while the main body of the metal maintains its consistency, and undergoes rapid oxidation, as is shown by the scales which are perpetually formed on its surface.

These metals are, however, in this condition rendered extremely ductile, and the wrought iron especially may be fashioned with facility into any required form, by the application of the hammer. On the contrary, pig iron, of which wrought iron and steel are preparations, has peculiarly the property of liquefaction by heat, and is therefore well adapted as a material for castings, in which strength and hardness are required.

The business of the founder is therefore to take advantage of the common law, according to which fluids always find their level. If, for example, a quantity of water be poured into a vessel, however

curiously shaped, it first finds the bottom, and then spreads on all sides as it rises, filling every corner it can reach. The body of water must then be a perfect model in form of the interior of the vessel, and this may be seen by solidifying it in its place by the application of cold, and extracting the body of ice.

To mould a quantity of melted metal into a desired form, two things are therefore necessary: first, a model, or pattern of the required form. Secondly, a substance of sufficient susceptibility and adhesiveness to receive accurately, and to retain impressions of that pattern made upon it, against the violence of the liquid metal, when run into the mould which is thereby formed.

ON BRASS FOUNDING.

BRASS FOUNDING, considered as a branch of engineering, is beset with a host of empirical rules and fancies, to an extent which naturally surprises the scientific practician, when he considers it with regard to the present calculating and philosophizing age.

Every founder thinks he possesses the only true and orthodox system of producing first-rate castings, and, as a matter of course, every one differs from his neighbour in his routine of practice, without reflecting that the process admits as fully of a reduction to scientific rules as any of its sister branches of the manipulatory art.

It is scarcely necessary to observe, that excellence can never be attained in any art in the prosecution of which so loose a system is tolerated: *guess-work* will ever give chance results, productive only of inconveniences and objections, which a more systematic code of regulations would entirely obviate. The number of alloys of copper which come under the generic name of brass, as has been shown, amount to a numerous family, and are of the greatest importance, not only to the engineer, but to artists generally, involving the use of the following different metals, all of which are required in a greater or less degree to suit the variety of operations where brass is indispensable: namely, copper, tin, lead, zinc, antimony, and, in some cases, nickel.

The first four of these metals are those in the greatest request for engineering purposes. The leading metal of this series, copper, was known to the ancients previous to the discovery of *malleable*

iron, and was applied to all the purposes for which the latter metal alone is now used.

Although we find brass frequently spoken of in the Scriptures, as well as in many portions of profane history, yet it is a well ascertained fact that this refers to copper; the brass of the present day being a discovery of much later date.

COPPER.

THE word copper is derived from the Island of Cyprus, where it was first wrought by the Greeks. The best method of obtaining it pure, where extreme purity is an object of importance, is to dissolve it in nitric acid: the solution is then diluted, and a piece of iron introduced, upon which the pure metal is precipitated, any adherent particles of iron being readily removed by washing with dilute sulphuric acid. Another method has lately been discovered of purifying copper, namely, by melting 100 parts of it, with 10 parts of copper scales (black oxide), along with 10 parts of ground bottle-glass, or other flux. Mr. Lewis Thompson, who received a gold

medal from the Society of Arts, for this invention, says that, after the copper has been kept in fusion for half an hour, it will be found at the bottom of the crucible, perfectly pure, while the iron, lead, arsenic, &c., &c., with which this metal is usually contaminated, will be oxidized by the scales, and will dissolve in the flux, or be volatilized. Thus he has obtained perfectly pure copper from brass, bell-metal, gun-metal, and several other alloys, containing from 4 up to 50 per cent. of iron, lead, bismuth, antimony, arsenic, &c. The scales of copper are cheap, being the product of every large manufactory. Copper melts at a white heat, and by slow cooling may be crystallized. Its specific gravity is 9, nearly. It melts at a temperature of 1996° Fahr.

On the Reduction of Copper.

THE reduction of copper ore is made by several consecutive processes. The *first* is by calcining it, and, when the *ore* is sufficiently "roasted" to oxidate the iron which it contains, it is melted. The melted metal is, after a time, suffered to flow into a pit filled with water, by which it becomes granulated.

It then undergoes further heating, and what is called technically its slag (or scoria) is taken off, and it is allowed again to run off into water.

After these processes it is cast in sand, when it becomes solid, and in this state is called "blistered copper."

It is now fit for what is called the refinery, and undergoes an operation called *refining*, or *toughening*. This is considered to be an operation of delicacy, and requires great skill and care in the workmen. It is conducted in a furnace similar to the melting furnace, and the object is to thoroughly purify the metal from any portions of oxygen, which is performed by adding charcoal to the copper, while it is in fusion, and stirring it occasionally, till it is judged to be pure.

TIN, OR BEDIL IN THE HEBREW.

The next metal on our list has also been known from the remotest ages. It is mentioned by Eleazar the priest in the book of Numbers, chapter 31st, verse 22d. All the other metals supposed to have

been then known are enumerated in the same passage. Thus, lexicographers form *bedil*, "to separate," tin being a separating metal. This carries the knowledge and use of *tin* back 1500 years antecedent to the commencement of our era. The Phœnicians used tin, of course, in the erection and decoration of the Temple of Solomon. Their brass was bronze; zinc had not then been discovered. We read of tin, also, having been got by the Carthaginian navigator, Himiles, from the Scilly Islands; they certainly present appearances of ancient excavations. Tin occurs, native, in two forms—as per oxide, and as sulphuret of tin and copper. The last is rare; the former constitutes the great source of tin, and, in its native mixed state with arsenic, copper, zinc, and tungsten, is called "tin-stone;" but, when occurring in rounded masses, grains, or sand in alluvial soil, is called stream tin. The metal reduced from the tin-stone forms *block tin*—that from the stream tin forms *grain tin*.

The greater part of the East Indian tin comes from Siam, Malacca, and Banca. The last place is an island near the south-east coast of Sumatra. The mines were discovered in 1711; in 1776 there were ten pits which were worked by the Chinese on account of the King of Palimbang. One hundred

and twenty-five pounds cost him only five rix dollars. The greater part went to Alinia, or was used in India.

On the Reduction of Tin, Grain, and Block Tin.

THE best ore of tin is found in Cornwall; it is commonly blasted by gunpowder, and is procured in pieces of considerable size, which are stamped, by beams shod with iron, to powder. It is then well washed, till the earthy particles are carried off, and the tin is fit for the smelting-house.

After being roasted in a reverberatory furnace, and again washed, it is a second time subjected to the furnace, being now mixed with small coal and, in some cases, with a small quantity of lime. The melted tin thus produced is at last placed in a small furnace, and exposed to a very gentle heat, when the purest portion melts first, and is drawn off. This is called "common grain tin." And the inferior, which still contains a small proportion of copper and arsenic, is then cast into pigs, called "block tin."

The purest tin is procured from the stream works of Cornwall, and affords from 65 to 75 per cent. of the best grain tin; its specific gravity is about 7.5.

it melts at a temperature of 442°. Like copper, it is the nucleus of an immense number of subsidiary metals, which it is our intention shortly to enter upon.

ZINC.

ZINC is a metal whose extensive range of application is only now beginning to be understood. It is found in the state of oxide and sulphuret; its specific gravity is about 7.7; its fusing point is 773°, but at a temperature of 300°, it becomes extremely malleable, and may be rolled into thin leaves, or drawn into fine wire. One of its most valuable modern applications, is as a protective covering for iron, being the best known substance for this purpose. The purifying of zinc may be effected by melting the impure metal with *lead*, in equal parts, in a deep iron pot, stirring them well together, skimming off the impurities as they rise, covering the surface with charcoal to prevent oxidation, and keeping them in a fused state for three hours. The lead descends to the bottom by its greater density, and leaves the zinc above, to be

drawn off by a pipe in the side of the melting-pot. This contrivance is the subject of a patent, granted to Mr. William Godfrey Kneller, in 1844.

LEAD.

LEAD was also known to the ancients. Its specific gravity is 11.4; melts at a temperature of 612°. This metal is highly poisonous, and the greatest amount of caution ought to be observed in its application to domestic purposes, as, when in contact with water in open vessels, it quickly tarnishes, and small crystalline scales of oxide of lead are formed, a portion of which dissolves in the water, and is again precipitated in the form of a carbonate. If, however, the water contains a very slight amount of sulphuric acid, or a soluble sulphate, the corrosion is prevented.

ANTIMONY.

ANTIMONY was discovered by Basil Valentine (a monk), in the fifteenth century. It is of a grayish-white, having a slight bluish shade, and very brilliant. Its texture is lamellated, and exhibits plates crossing each other in every direction. Its surface is covered with herbarizations and foliage. Its specific gravity is 6.702. It is sufficiently hard to scratch all the soft metals; it is very brittle, easily broken, and pulverizable. It fuses at 810° Fahr.; it can be volatilized, and burns by a strong heat When perfectly fused and suffered to cool gradually, it crystallizes in octahedra. It unites with sulphur and phosphorus. It decomposes water strongly. It is soluble in alkaline sulphates; sulphuric acid boiled upon antimony, is feebly decomposed. Nitric acid dissolves it in the cold; muriatic acid scarcely acts upon it. The oxygenated muriatic gas inflames it, and the liquid acid dissolves it with facility. Arsenic acid dissolves it by heat with difficulty. It unites by fusion with gold, and renders it pale and brittle. Platina, silver, lead, bismuth, nickel, copper, arsenic, iron, cobalt, tin, and zinc unite with

antimony by fusion, and form with it compounds more or less brittle. Mercury does not alloy with it easily. We are little acquainted with the action of alkalies upon it. Nitrate of potash is decomposed by it. It fulminates by percussion with oxygenated muriate of potash.

THE order and facility of working these metals vary considerably with the purpose to which they are applied. Thus, regarding their wire-drawing ductibility, gold is the most ductile metal, being 1. The four first metals are as follows: copper 5, zinc 6, tin 7, lead 8. Their relative values as laminable substances are considerably different: thus, under the same circumstances, copper is 3, tin 4, lead 6, zinc 7.

The following tabulated statements exhibit the most approved properties of the most useful class of alloys, as laid down by the best authorities, together with the specific purposes to which they are adapted. The first we shall treat upon are the alloys of copper and tin. In this table the quantity of tin is that which is added to one pound of copper.

COPPER AND TIN.

1	ounce,	Soft gun metal.
1½	"	A slightly harder alloy, fit for mathematical instruments.
1½	"	Still harder, fit for wheels.
1½ to 2	"	Brass guns.
2 to 2½	"	Hard bearings for machinery.
3	"	Musical bells.
3½	"	Chinese gongs, cymbals, &c.
4	"	Small house bells for domestic purposes.
4½	"	Large do.
5	"	Largest bells, for churches, &c.
7 to 8	"	Speculum metal for the reflectors of telescopes, light-houses, &c.

Temper, is a mixture of 2 pounds of tin to 1 pound of copper, and is used for adding to tin in the manufacture of pewter; the object being tc introduce an extremely small quantity of copper.

BRONZE FOR CANNON, STATUES, ETC.

BRONZE is an alloy of copper, with from 8 to 10 per cent. of tin, together with small quantities of other metals, which are not essential to the compound. Cannons are cast with an alloy of a similar kind, and the ancient bronze statues were of the same composition.

ON BELL METAL.

BELL METAL is a compound of 80 parts copper to 20 parts tin. The Indian gong, so much celebrated for the richness of its tones, contains copper and tin, in the above proportions. The proportion of tin in bell metal varies, however, from one-third to one-fifth of the weight of copper, according to the sound required, the size of the bell, and the impulse to be given. M. d'Arcet has discovered that bell metal formed in the proportion of 78 parts copper, united with 22 of tin, is indeed nearly as brittle as glass, when cast in a thin plate or gong. Yet if it be

heated to a cherry-red, and plunged into cold water, being held between two plates of iron, that the plate may not bend, it becomes malleable. Thus he manufactures gongs, cymbals, and tantums out of this compound.

ON COPPER AND TIN MIXTURES.

THE above are the best proportions in use at the present day; for some other peculiar objects a slightly different mixture is adopted, as a small amount of zinc or silver, and even arsenic. The best mode of mixing the component metals of this alloy, appears to be to melt each separately, and then to add the tin to the copper at the lowest stirring temperature. To complete the combination the alloy is again melted very gradually by placing the metal in the crucible almost as soon as the fire is lighted. The hardness of this alloy, compared with the extreme softness of the metals, gives us an example of the chemical changes effected by their combination. Thus, the speculum metal, as used by Lord Rosse, is totally devoid of malleability, and from its hardness cannot be acted on by the file.

His speculum consisted of four atoms of chemical combining proportions of copper to one of tin: or, by weight, 126.4 copper to 58.9 tin. This alloy, which is a true chemical compound, is of a brilliant white lustre; its specific gravity 8.811; nearly as hard as steel, and almost as brittle as sealing-wax. The speculum is six feet in diameter, five and a half inches thick. It was cast open, ground with emery, placed on a table in a cistern filled with water at a temperature of 55° Fahr., polished with red oxide of iron, procured by precipitation from green vitriol, or sulphate of iron, by water of ammonia.

ALLOYS OF COPPER AND ZINC.

We now come to the consideration of another branch of the copper alloy family of great value in the arts. This is copper and zinc.

The following table contains the best proportions of the principal mixtures. In this table the quantity of zinc is that which is added to one pound of copper.

⅛ to ½	ounce.	This addition is used principally for the purpose of producing sound copper castings.
1 to 1½	"	Gilding metal for jewellers.
2	"	Tombac, or red brass.
3 to 4	"	Red sheet brass, pinchbeck, and bath metal.
5	"	Purbeck metal.
6	"	Bristol brass. This and the five preceding mixtures solder well.
7 to 7½	"	Good dipping metal.
8	"	The general proportion for all ordinary brass articles.
10⅜	"	Muntz's metal, for ships' fastenings, sheathing, &c.
14	"	Strong brazing solder, for heavy copper work, &c.
16	"	Soft spelter solder.

From the volatile nature of zinc the above proportions can seldom be strictly adhered to; but a slight variation does not much affect the filing and working of the metal.

An alloy of copper and lead is often used in place of gun metal for inferior work, on account of its

cheapness and facility of manipulation. It is very brittle, particularly where much lead is used.

The whole of the different metals just discussed, when mixed together, constitute gun metal, or brass, *par excellence*. This alloy is applied to a very great variety of purposes, and is the one most in demand for engineering works. The principal ones are compounded as below.

ALLOYS OF COPPER, ZINC, TIN, AND LEAD.

1½ ounces tin, ½ ounce zinc, and 16 ounces copper, constitute an extremely tenacious metal, used where great strength is required.

1½ ounces tin, 2 ounces brass, 16 ounces copper, for wheels, &c.

2 ounces tin, 1½ ounces brass, 16 ounces copper, for articles requiring turning.

2¼ ounces tin, 1½ ounces brass, 16 ounces copper, for bearings, nuts, &c.

1⅞ ounces tin, 1⅞ ounces zinc, 16 ounces copper a composition for general purposes, used by an eminent engineer.

HAVING discussed the *rationale* of the mixture and proportion of the metals used in alloys of copper, the matter leads us to the further consideration of casting them. Brass moulding is carried on by means of earthen, or sand moulds. The formation of sand moulds is by no means so simple an affair as it would at first sight appear to be, as it requires long practical experience to overcome the disadvantages attendant upon the material used. The moulds must be sufficiently strong to withstand the action of the fluid metal perfectly, and, at the same time, must be so far pervious to the air as to permit of the egress of the gases formed by the action of the metal on the sand. If the material were perfectly air-tight, then damage would ensue from the pressure arising from the rapidity of the generation of the gases, which would spoil the effect of the casting, and probably do serious injury to the operator.

If the gases are locked up within the mould, the general result is what moulders term a *blown* casting; that is, its surface becomes filled with bubbles of air, rendering its texture porous and weak, besides injuring its appearance.

Plaster of Paris is often used for a number of the

more fusible metals. This material, however, will not answer for the more refractory ones, as the heat causes it to crumble away and lose its shape.

Sand, mixed with clay or loam, possesses advantages not to be found in gypsum, and is consequently used in place of it, for brass and other alloys. In the formation of brass moulds, old damp sand is principally used in preference to the fresh material, being much less adhesive, and allowing the patterns to leave the moulds easier and cleaner.

Meal dust or flour is used for facing the moulds of small articles; but for larger works, powdered chalk, wood-ashes, &c., are used, as being more economical.

If particularly fine work is required, a *facing* of *charcoal* or *rottenstone* is applied. Another plan for giving a fine surface is to dry the moulds over a slow fire of *cork shavings*, or other carbonaceous substance, which deposits a fine thin coating of carbon. *This*, when good fine facing-sand is not to be obtained.

As regards the proportions of sand and loam used in the formation of the moulds, it is to be remarked, that the greater the quantity of the former material, the more easily will the gases escape, and the less

likelihood is there of a failure of the casting; on the other hand, if the latter substance predominates, the impression of the pattern will be better, but a far greater liability of injury to the casting will be incurred from the impermeable nature of the moulding material. This however may be got over without the slightest risk, by well drying the mould prior to casting, as you would have to do were the mould entirely of loam.

For some works, where easily fusible metal is used, metallic moulds are adopted. Thus, where great quantities of one particular species of casting is required, the metallic mould is cheaper, easier of management, and possesses the advantage of producing any number of exactly similar copies. The simplest example which we can adduce is the casting of bullets. These are cast in moulds constructed like scissors, or pliers, the jaws or nipping portions being each hollowed out hemispherically, so that when closed a complete hollow sphere is formed, having a small aperture leading into the centre of the division line, by which the molten lead is poured in.

Pewter pots, inkstands, printing types, and various other articles, composed of the easily fusible metals, or their compounds, are moulded on the

same principle. The pewterer generally uses brass moulds: they are heated previous to pouring in the metal. In order to cause the casting to leave the mould easier, as well as to give a finer face to the article, the mould is brushed thinly over with red ochre and white of an egg; in some cases, a thin film of oil is used instead.

Many of the moulds for this purpose are extremely complex, and, being made in several pieces, they require great care in fitting.

With these peculiar cases we have, at present, little to do, and shall conclude with a few observations on the method of filling the moulds. The experienced find that the proper time for pouring the metal is indicated by the wasting of the zinc, which gives off a lambent flame from the surface of the melted metal. The moment this is observed, the crucible is to be removed from the fire, in order to avoid incurring a great waste of this volatile substance. The metal is then to be immediately poured. The best temperature for pouring, is that at which it will take the sharpest impression and yet cool quickly. If the metal is very hot, and remains long in contact with the mould, what is called *sand-burning* takes place, and the face of the casting is injured.

The founder, then, must rely on his own judgment, as to what is the lowest heat at which good, sharp impressions will be produced. As a rule, the smallest and thinnest castings must be cast the first in a pouring, as the metal cools quickest in such cases, while the reverse holds good with regard to larger ones.

Complex objects, when inflammable, are occasionally moulded in brass, and some other of the fusible metals, by an extremely ingenious process; rendering what otherwise would be a difficult problem a comparatively easy matter.

The mould, which it must be understood is to be composed of some inflammable material, is to be placed in the sand-flask, and the moulding sand filled in gradually until the box is filled up. When dry, the whole is placed in an oven sufficiently hot to reduce the mould to ashes, which are easily removed from their hollow, when the metal may be poured in. In this way (as will be afterwards shown) small animals, birds, or vegetables may be cast with the greatest facility.

The animal is to be placed in the empty moulding-box, being held in the exact position required, by suitable wires or strings, which may be burnt or removed, previous to pouring in the metal.

Another mode which appears to be founded on the same principle, answers perfectly well when the original model is moulded in wax. The model is placed in the moulding-box in the manner detailed in the last process, having an additional piece of wax to represent the runner for the metal. The composition here used for moulding is similar to that employed by statue founders in forming the cores for *statues*, *busts*, &c., namely, two parts brick-dust to one of plaster of Paris. This is mixed with water and poured in so as to surround the model well. The whole is then slowly dried, and when the mould is sufficiently hardened to withstand the effects of the molten wax, it is warmed, in order to liquify and pour it out. When clear of the wax, the mould is dried and buried in sand, in order to sustain it against the action of the fluid metal.

If our limits permitted, we might mention the details of numerous other works in the founding of brass. We must for the present content ourselves with a brief examination of one or two cases which come more or less within the province of the engineer. One of these is the founding of bells, a subject of considerable interest, as works of this kind are often of very considerable magnitude, and demand the skilful attention of the engineer. Large

bells are usually cast in loam moulds, being *swept* up, according to the founder's phraseology, by means of wooden or metal patterns, whose contour is an exact representation of the inner and outer surfaces of the intended bell. Sometimes, indeed, the whole exterior of the bell is moulded in wax, which serves as a model to form the impression in the sand, the wax being melted out previous to pouring in the metal. This plan is rarely pursued, and is only feasible when the casting is small.

The inscriptions, ornaments, scrolls, &c., usually found on bells, are put on the clay mould separately, being moulded in wax or clay, and stuck on while soft. The same plan is pursued with regard to the ears, or supporting lugs, by which the bell is hung.

BRASS GUNS

ARE another important branch of this manufacture. They are moulded in a manner quite distinct from any other work of this nature. The exterior surface of the gun is produced by wrapping gaskin or soft rope round a tapered rod, of a length slightly

greater than that of the gun. Upon this foundation of rope the moulding loam is then applied; the surface being turned to the exact shape and proportions of the gun.

A long fire is used by the founder in this process, in order to dry the mould as he proceeds in its manufacture. When perfectly dry, the surface of the mould is black-washed over, and again covered with loam to a depth of two or three inches. This exterior coat of loam is secured and strengthened by a number of iron bands, and the whole is well dried. The primary mould is now completely withdrawn from the outer shell, the formation of which renders it an easy matter, as the timber rod leaves the rope with great facility, when the latter may be withdrawn, and the clay covering picked out afterwards.

The trunnions of the gun are formed separately, and attached to the shell in the ordinary way. When finished, the moulds are sunk perpendicularly in a sand pit, near a reverberatory furnace, a vertical runner being made, leading to each mould, which it enters near the bottom. A suitable channel communicates with the furnace containing the brass intended for the guns. The metal being in-

troduced at the bottom of the mould, no air can possibly be detained by its entrance, as each mould is full open to the atmosphere at the top.

FIGURE CASTING

Is another branch of our subject, and one which, from its general complexity, ranks as the greatest effort of the founder. As an example of this process we shall take the moulding of thin ornaments in relief.

The ornament, whatever it may be, a monumental bas-relief for instance, is first modelled in relief, in clay or wax, upon a flat surface. A sand flask is then placed upon the board, over the model, and well rammed with sand, which thus takes the impress of the model on its lower surface. A second flask is now laid on the sunken impression, and also filled with sand, in order to take the relief impression from it. This is generally termed the *cope*, or *back mould*. The thickness of the intended cast is then determined by placing an edging of clay round the lower flask, upon which edging the upper one rests, thus keeping the two surfaces at the precise

distance from each other, that it is intended the thickness of the casting shall be.

In this process, the metal is economised to the greatest possible extent, as the interior surface, or back of the casting, is an exact representation of the relief of the subject; and the whole is thus made as thin in every part as the strength of the metal permits.

Several modifications of the process just described are also made use of, to suit the particular circumstances of the case. What we have said, however, is a detail of the principle pursued in all matters of a similar nature. In conclusion we will give a composition for cores that may be required for difficult jobs, where it would be extremely expensive to make a core-box for the same:—

Make a pattern (of any material that will stand moulding from) like unto the core required. Take a mould from the same in the sand, in the ordinary way; place strengthening wires from point to point, centrally; gate and close your flask. Then make a composition of two parts brick-dust and one part plaster of Paris; mix with water and cast. Take it out when set, dry it, and place it in your mould warm, so that there may be no cold air in it.

MALLEABLE IRON CASTINGS.

THE term malleable iron castings means an iron that has been cast into any desired shape, and then rendered malleable by removing the carbon by a process of annealing, which consists in burning off the whole or a part of the carbon combined with the iron from which the castings were made. In the manufacture of malleable iron castings, the first object is to get the proper kind of pig-iron, for all iron is not suitable for making malleable iron by the process of annealing. From the states in which carbon exists in cast-iron, the latter has been classified into three principal subdivisions. The first is "grey metal," or "No. 1 foundry pig," in which the carbon is not combined with the iron, but is in the graphitic state, and may be seen in large flakes when the iron is broken. These flakes are sometimes called "tissue" and "black-lead." The second division is "mottled" cast-iron. In this the carbon is partly combined with the iron and partly in the graphitic state, which gives the iron a spotted or mottled appearance. The third division is "white" cast-iron. In this the carbon is combined with the iron, and is unseen.

Gray or No. 1 foundry iron is best for ordinary castings, because it contains the most carbon, and is softer and will remain fluid longer than either the mottled or white iron, yet it is not best for malleable castings, for the carbon in it is not combined with the iron, and in converting the castings into malleable iron the carbon is extracted from the iron without melting the castings. If this class of iron is used the castings will be full of small holes after they have been rendered malleable, and will not have the required strength.

White cast-iron will make the best malleable castings, because in this the carbon is completely combined with the iron, and when it is abstracted from it by the annealing process, it leaves a perfectly sound and smooth casting. But in using this iron for malleable castings another trouble arises. The iron contains so little carbon that it will not retain its fluidity long enough to be run into light castings—and almost all malleable castings are very light—so that this class of iron cannot be used.

As the gray or No. 1 foundry iron contains too much carbon and the white iron too little carbon, the best iron for malleable castings must be the mottled iron, which is between the two extremes. This iron is always used for malleable iron castings, and none

but the very best brands of cold-blast charcoal mottled iron will produce a good malleable casting.

Iron for malleable castings may be melted in a cupola or in a reverberatory furnace. However, the iron melted in the latter always produces by far the best castings; for the iron is not melted in contact with the fuel, as in the cupola, and is not deteriorated by the impurities contained in the fuel. There is also the advantage that, should the iron contain too much carbon, part of it may be removed by the oxidizing action of the flame.

As most malleable castings are very small, they are generally moulded in snap-flasks, with green sand, from metallic patterns or match plates. The castings, before they are annealed, are as hard and brittle as glass, and must be handled with care to prevent breaking. These castings are put into a tumbler or rattle-barrel, where they are cleansed from all adhering sand, and become polished by mutual friction. To anneal them properly, it is very essential that they should be thoroughly cleansed. The cleansed castings intended for conversion into malleable iron are next packed into iron boxes, with alternate layers of fine iron scales from rolling-mills. The boxes are then closed at the top by a mixture of sand and clay, and all the cracks are carefully

luted, to prevent the admission of air. The boxes are next put into the annealing oven, where they are subjected to a white heat, not sufficiently hot, however, to melt the boxes. They are kept at this heat for a week or more, and then allowed to cool off gradually. After the castings have been properly annealed, they are covered with a film of oxide of different colors, and resemble in appearance that kind of iron ore called peacock ore. These various colors are a sign of good malleables. This adherent oxide is removed from the castings by another passage through the rattle-barrel, and the process of malleable iron making is finished.

Powdered iron ore is sometimes used in place of iron scales, but it is not so good, for it contains more or less silica and earth, which, at the temperature of the annealing oven, will fuse and form a slag or cinder, and prevent the oxidizing action on the castings. For this reason, scales are to be preferred, and care should always be taken to keep them as free from earthy matter as possible. In every "heat" or annealing operation, the scales part with some of their oxidizing properties, and before they are again used they must be pickled and reoxidized. This is done by wetting them with a solution of sal ammoniac and water, and mixing and drying them until they are

thoroughly rusted, when they are again ready for use. The annealing boxes were formerly made of soft iron, but at present they are mostly made of hard iron—the same as the castings are made of. The hard iron boxes become annealed the same as the castings, and will last longer than the soft iron boxes. These boxes are generally made about 20 inches long by 14 inches wide and 14 inches deep. They are set one on top of another in the annealing oven, but never more than two high. The lower one has a bottom cast in it, but the top one has no bottom, and is merely a frame set on the lower box. These boxes only last a few heats, and the smaller boxes are said to last longer than the larger ones.

There are several different kinds of annealing ovens in use, and some very important improvements have been made in their construction in the last few years. The best in use at the present time is one with a fire on each side of it, and so arranged that the flame from the fuel does not enter the oven or strike the boxes. This oven is not allowed to cool off, but is kept hot all the time. At one end there is a door through which the annealing boxes are removed while at a white heat, and are replaced by cold ones. The door is then closed, and the boxes heated to the required degree. This kind of oven is most econo-

mical in use, for it requires less fuel than any other, and is not injured by expansion and contraction in cooling and reheating, as the other ovens are. When annealing the castings in the oven, care should be taken not to have the temperature of the oven too high, nor the heat too prolonged, or the castings may be burned and hardened after they have been softened. After the castings have been thoroughly decarbonized by annealing in the oven, they are virtually a commercially pure iron, and are the same as wrought-iron without fibre, and fibre may be imparted to them by rolling or hammering. Yet these castings without fibre are sometimes equal to the best wrought iron for strength, and may be bent double when cold without breaking them.

The process is conveniently applicable only to small castings, although pieces of considerable size are sometimes thus treated. Handles, latches, and other similar articles, cheap harness-mountings, ploughshares, iron handles for tools, wheels, and pinions, and many small parts of machinery, are made of malleable cast-iron. For such pieces charcoal cast-iron of the best quality should be selected, in order to ensure the greatest possible purity in the malleable product. The castings are made in the usual way, and are then imbedded in oxide of iron—

in the form, usually, of hematite ore—or in peroxide of manganese, and exposed to the temperature of a full red heat for a sufficient length of time to ensure the nearly complete removal of the carbon. The process with large pieces requires many days. If the iron is carefully selected, and the decarbonization is thoroughly performed, the castings are nearly as strong, and sometimes hardly less malleable, than fairly good wrought-iron, and they can be worked like that metal. They will not weld, however. The pig-iron should be very free from sulphur and phos phorus. The best makers have usually melted the metals in crucibles having a capacity of 50 to 75 lbs., keeping it carefully covered to exclude cinder and other foreign matter. The furnace is similar to that of the brass foundry, 2 to 2½ feet square, and the fire is kept up by natural draught. The temperature is determined with sufficient accuracy for the practical purposes of the iron-founder by withdrawing a portion on an iron bar. If hot enough, the drop burns on exposure to the air. If right, the metal is poured quickly. The "cementation" or decarbonization is conducted in cast-iron boxes, in which the articles, if small, are packed in alternate layers of the decarbonizing material. As a maximum about 800 to 1000 lbs. of castings are treated

at once. The largest pieces require the longest time. The fire is quickly raised to the maximum temperature, but at the close of the process the furnace is cooled very slowly. The operation requires 3 to 5 days with ordinary small castings, and may take two weeks for large pieces. Decarbonization is often performed, in the production of steel castings, by a process of dilution, accompanied with possibly some "dissociation." By the preceding method the carbon takes oxygen from the surrounding oxides, and passes off as carbon monoxide (carbonic oxide). In the process now referred to the carbon of the cast iron is shared between the latter and the wrought iron mixed with it in the melting pot, and a small portion may possibly pass off oxidized. The latter method has been practiced to some extent for a century. Selected cast-iron and good wrought-iron are melted down together in a crucible, and cast in moulds like cast-iron. The metal thus produced contains a percentage of carbon, which is determined by the proportions of cast and wrought-iron in the mixture. The amount is frequently so small that the castings can be forged like wrought-iron.

WROUGHT-IRON (OR MITIS) CASTINGS.

WHEN wrought-iron is heated to a high temperature it does not pass quickly into the fluid state, but for a large increase of temperature above the point at which it first softens it will remain thick or mushy. At a very high temperature it can be made sufficiently fluid to pour into moulds, but the castings then made are notably unsound and weak. It was discovered by Mr. Wittenstroem, of Stockholm, working with the co-operation of Mr. L. Nobel, of St. Petersburg, that if a small amount of aluminium is added to a charge of wrought-iron which has been heated until pasty, the iron immediately liquefies and can be poured into castings having all the properties of wrought-iron except fibre, and as sound as if of cast-iron. These castings were called "Mitis" castings, because of their softness in contrast with iron castings.

The advantages of an addition of aluminium to fluid iron are important. With moderate care absolutely pure and solid castings can be obtained, capable of receiving a high polish. An addition of aluminium is especially to be recommended for the manufacture of steam cylinders, engine castings, press

cylinders, and generally for castings which are to be subjected to a high pressure. A few hints will serve to show how aluminium is best alloyed with iron. As aluminium only lends itself with difficulty to combination with iron, it is not immediately to be introduced in the ladle which is to be poured into the mould; a smaller ladle is selected, in which is placed the heated aluminium. Somewhat fluid iron is then brought from the furnace, poured in the ladle, and stirred until the aluminium compound begins to stiffen. The iron intended to be cast is now let out of the furnace into the ladle intended for it, the aluminium-mixture is poured in, and the whole intimately mixed. The melted metal should not be poured into the mould too quickly, as it does not solidify as rapidly as ordinary iron. Aluminium-iron in the fluid condition is very active; small globules are formed, which gradually extend to the edge of the ladle, where they disappear. At first the iron is of a milk-white color; then it becomes orange-yellow, and forms a thin film on the top. When this moment has arrived, the film is removed, and casting is proceeded with, care being taken that the mould is always kept full. For 100 lbs. the proportion of aluminium recommended is about $3\frac{1}{2}$ ounces. Cost can be no drawback in view of the pres-

ent comparative cheapness of aluminium, particularly when it is considered with how much greater certainty clean castings can be obtained. Aluminium improves cast-iron as phosphorus improves tombac and brass, the fluidity being increased and the oxide separated.

The details of the production of Mitis castings are as follows: As the raw material to operate on, wrought iron, scrap or mild steel are equally suitable. It was found that some of the best results are to be obtained by using Swedish scrap or English hematite iron, that is, materials containing less than 0.1 per cent. of phosphorus, which is a very injurious ingredient if present in much larger quantity. Using a mixture with poorer quality of iron, with phosphorus running up to 0.15 per cent., good results may still be obtained—that is, the castings will compare favorably with ordinary malleable castings. In using scrap-steel, which is necessarily low in phosphorus, it was found that manganese interfered with the production of good castings, a result rather unexpected. Since almost every melter devises various mixtures of his own, as circumstances permit, it is but natural that the best features of the Mitis process are found united with some other old established practices. Thus, in one Mitis plant in the

United States the mixture for melting was composed of: Mitis scrap 35 per cent., hematite muck bar, 35, wrought iron punchings, 12⅔, soft steel scrap (0.1 per cent. carbon), 12⅔; white pig iron, 3; ferro-silicon (10 per cent. silicon), 1; ferro-aluminium (6 per cent. aluminium), ⅔. It seems that in this charge the melter used a little white iron as a flux, which would probably introduce 0.1 per cent. of carbon; then the virtues of ferro-silicon for making sounder castings are utilized by adding 0.1 per cent. of silicon to the charge; lastly, 0.04 per cent. of aluminium was introduced.

In general it may be said that if iron free from impurities is used, very good castings are obtained; if iron is used with a large percentage of phosphorus, proportionally brittle and unsatisfactory castings result.

The ferro-aluminium should be, for similar reasons, free from any considerable amount of such impurities as generally injure wrought iron.

Since the castings are almost identical in composition with the charge of iron melted, the following analyses of mitis metal, made by Mr. Edward Riley, will show the range of material or mixture to which the process has been successfully applied:

Raw Material.	Carbon.	Silicon.	Phosphorus.	Manganese.
Hematite bar	0.067	0.161	0.068	0.022
Swedish scrap. . . .	0.053	0.044	0.077	0.027
Refined iron	0.130	0.124	0.137	0.014
½ Staffordshire iron ½ Swedish scrap.	0.130	0.035	0.150	0.026
¾ Staffordshire iron ¼ Hematite bar.	0.070	0.093	0.194	0.014
Staffordshire iron . .	0.106	0.080	0.250	0.014

The above figures are percentages; sulphur was present in all as a trace. The first in the table, those low in phosphorus, gave the best castings, the last the poorest; with over ¼ per cent. of phosphorus the castings were brittle.

The charge of wrought iron is placed in covered crucibles and brought to a temperature of about 2200° C., at which heat it just loses the solid and assumes the pasty condition. If it were desired to cast the iron without adding aluminium, it would be necessary to superheat it several hundred degrees above this point, not only to give it the desired fluidity, but also to permit it being carried about the casting shop. It is during this superheating that a large part of the gases contained in the melted iron are absorbed. If, therefore, the charge is treated with aluminium immediately on reaching the melting point, the effect is such that this superheating with its accompanying deteriora-

tion of the iron is rendered unnecessary. This is possible for the reason that on adding ferro-aluminium sufficient to introduce 0.05 to 0.1 per cent. of aluminium, the charge immediately liquefies, and is so far from its setting point that it can be removed from the furnace and poured into numerous moulds, retaining all the time its exceptional fluidity. The metal acts just as if it had been super-heated several hundred degrees, but this has been accomplished without leaving it in the furnace for half an hour or so, thus attaining an economy of fuel, which is not to be ignored. When the crucible is taken from the furnace the charge is perfectly *dead melted*, lies quiet in the crucible, evolves no gas, and teems like melted silver. It is cast in either sand or iron moulds, and on account of its fluidity does not require large heads to bring the castings up sharp and show the finest impressions of the mould. The material being primarily wrought-iron, the castings do not have to be annealed before using. The thinnest and most complicated castings, which it would be almost impossible to forge in wrought-iron, can be produced, thus furnishing difficultly forged pieces at not much greater expense than ordinary castings. Mitis castings are, in short, objects cast of melted iron, yet having all the desirable properties of wrought-iron.

MANUFACTURE OF STEEL CASTINGS.*

A LARGE number of so-called steel castings are nothing more than malleable iron. The best of these castings are made from superior white pig, as low in silicon and phosphorus as possible. They are made in the same manner as ordinary iron castings, except that the metal having so little silicon chills much quicker than ordinary No. 1 foundry iron, and the liability to shrinkage-cracks renders it necessary to put large "rising-heads" on the castings. The castings after cooling are very hard, and almost as brittle as glass, and are, or should be preferably, *perfectly white* throughout. They are then annealed in ore or scale, to which a little sal ammoniac has been added. This latter operation, which requires about two weeks, produces on the entire surface of the casting a coating of malleable iron about $\frac{1}{16}$ of an inch thick, and renders the inside sufficiently soft to be tooled without any difficulty. For small castings such a metal is admirably adapted, but castings several inches thick made in this way are only slightly superior to good pig-iron in having, perhaps, a little greater tensile strength.

* Abstracted from a paper by Mr. P. G. Salom, read before the American Institute of Mining Engineers, May, 1885.

Crucible steel castings are a failure and always will be. By this statement it is not meant to say that it is impossible to make such castings satisfactory. But with the single exception of a particular class of work where hardness and ultimate strength are alone desired (for which requirements they are well adapted), there are always a number of disturbing elements that will eventually result in the total disuse of crucible castings. The value of small steel castings depends on the possession of qualities that render them equal or superior to forgings. When it is attempted to make a steel with the requisite qualities the troubles begin. First, in order to get such a steel, muck-bar must be used almost exclusively. This, as every one knows, is very difficult to melt in a crucible furnace, and after melting it is almost impossible to pour it, as the metal chills before the pots can be emptied. If, however, after unusual exertions, a successful cast be made, the castings are found to be full of blow-holes. There are two means employed to remedy the latter defect: first, by the use of ferro-silicon, and second, by making a steel higher in carbon and therefore more fusible. When sufficient ferro-silicon is added to give from 0.5 to 1.0 of silicon in the steel, the metal is not difficult to melt, but the resulting castings.

while soft and solid, have lost all their ductility, and are simply a superior form of pig-iron, with a tensile strength of about 50,000 lbs. If, on the other hand, the pots are charged with stock higher in carbon and only a small percentage of ferro-silicon is added, the castings are solid, but are brittle, and so hard as to be difficult to tool. Their hardness is extremely objectionable to machinists, but their brittleness is a still greater evil, and precludes the possibility of their replacing forgings. It has been attempted to overcome the latter difficulty by annealing, and by this means a really superior crucible casting can be made. But the additional cost of production is greater than consumers are willing to pay for the castings.

Bessemer steel castings. The Bessemer process in the manufacture of steel castings is as yet open to the objection of making a less homogeneous and a harder metal than the open hearth. Some time ago, a number of large Bessemer steel cranks, weighing from 7,000 to 8,000 lbs. each, broke in half when it was attempted to shrink them on the shafts for which they were intended. Notwithstanding these failures, it is believed that in the near future all steel castings will be made by the Bessemer or an equivalent pneumatic process.

Open-hearth steel castings. This method can be relied upon to make a very large class of important castings with entire success. According to Mr. Alexander L. Holley* the operation consists:

"1 In the formation of an initial bath of manganiferous pig to prevent oxidation during the process.

"2 In dissolving such softening or decarbonizing materials as wrought-iron in this bath.

"3 In the addition, at the end of the operation, of silicon and manganese in such order and proportion as to prevent the formation of blow-holes while casting, and at the same time to give to the steel certain special physical qualities.

"Another very important feature of the process is the method of taking tests. We will now describe in detail the different stages of the operation, and we will suppose at first, so as to avoid confusion, that the metal to be produced is of the harder kind.

"*The Furnace.*—The object of greatest importance during the whole of the operation is *to keep oxidation as low as possible in the bath.* For this reason the furnace must, indeed, be kept as hot as

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* *Solid Steel Castings for Ordnance, Structures and General Machinery by the Terrenoire Process.* By A. L. Holley, C. E. (Reprint from the *Metallurgical Review*, New York, 1878, vol. ii. p. 205.)

possible, with a good solid body of flame; but there should be only just enough air admitted to promote thorough combustion.

"*The Initial Bath.*—This must be made of pig iron containing from 6 to 7 per cent. of manganese. Spiegeleisen is probably the most convenient form of pig; but as spiegel with this percentage may not be at hand at all times, the bath may be formed by taking a richer spiegel, say 12 or 14 per cent. manganese, and diluting it with one-half ordinary pig containing no manganese.

"The weight of the initial bath, in proportion to that of the whole charge, varies according to the conditions under which the heat is made. We may say, generally, that 11 per cent. of the whole is an average quantity. Every open-hearth melter knows that it is impossible to determine in advance the exact quantity of pig wanted for the operation. The temperature of the furnace has much to do with it. The nature of the refining material has also a great influence. If a specially pure product is required and the softening materials used are very fine puddled blooms, nearly free from carbon and manganese, the initial bath must necessarily be larger, as well as richer in manganese; it may in this case reach 14 per cent. of the whole charge. The materials for the initial bath are always charged cold.

"*The Softening or Refining Materials.*—Soon after the bath is completely melted, the refining materials are successively added in small lots of about 450 lbs. each. These are invariably preheated, as charging them cold and frequently would tend to keep down the temperature of the bath.

"The materials used in this second period of the operation are chosen with reference to the quality required in the finished product. They may be good Bessemer or open-hearth scrap, fountains from previous castings, puddled bars or direct blooms. Materials inferior to these would correspondingly lower the quality of the product. The proportion of refining materials to the whole charge averages 78 per cent.

"*Slag-tests.*—Spiegeleisen is used for the initial bath, because the manganese it contains, being the most oxidizable of all the materials present, will remove oxygen that may be present in the bath, and will intercept oxygen that tends to enter it. So that the more manganese there is in the slag, the less oxygen there will be in the metal below. Oxide of iron tends to make the slag black; manganese turns it light olive or ash-green, and the different tints between these two extremes give to the practiced eye an exact idea of the state of the oxidation of the bath.

"*Metal-Tests before the Final Additions.*—The

holes in castings are due to carbonic acid gas, disengaged during the operation of casting. This is only true to a very limited extent, especially where the steel contains 0.1 per cent. or more of silicon. Herein lies the cause of the many failures connected with the manufacture of steel castings. The manufacturers had been led to believe that it was only necessary to add a few pounds of ferro-silicon to their steel, and presto! all their castings would be solid. Practical experience has proved the fallacy of this idea.

Blow-holes in steel which has been properly melted, and to which has been added sufficient ferro-silicon, are almost entirely due to the high melting-point of low-carbon steel, or rather to the rapidity with which the metal chills. This is proved by the fact that the lower ends of castings which have been fed from the bottom by means of a runner are always solid, while the blow-holes, when such exist, are always on top.

The difficulty connected with blow-holes has almost entirely been overcome by putting on top of the casting a rising-head from 2 to 3 feet high. By this means 6000-pound steel rolls without a single blow-hole or flaw of any kind have been made.

The long riser is effective in two ways: First, it carries from the casting proper the sluggish metal,

which has been cooled in its passage through the mould, and allows the mould to be filled with hot fluid metal; and second, the ferrostatic pressure of a column of iron 3 feet high is equal to about 10 pounds to the square inch. This pressure has a tendency of course to force the metal into all the corners and make it solid. It also prevents, in a measure, shrinkage troubles, and appears to give to steel castings that solidity for which they are noted, giving them a density of 7.8, almost equal to that of a forging.

Shrinkage. This presents a difficult and troublesome problem which has not yet been fully solved. It is almost impossible to make certain large, thin, complicated castings of steel. Shrinkage troubles are caused by the immense contraction of cast-steel, which frequently amounts to $\frac{5}{16}$ inch per foot; and to the hard dry sand moulds, which it is necessary to use in order to prevent the white-hot metal from destroying the mould.

There are five different ways of attempting to remedy this evil:

1. By changing the chemical constitution of the steel.
2. By stripping the castings as soon as poured.
3. By mechanical pressure.

CASTING OF BRASS.

MODELLING and pattern-making are both used brass work, and although these are distinct bran of trade from founding, where work is systematic performed, yet there are many work-shops whe is of great importance that the same man should able to execute work and understand the ger principles both of modelling and pattern-making well as of brass founding.

The materials commonly employed for model are pipe-clay and stucco. The former is used work of a protracted nature, the latter for stra flat models, which can be finished off at once. F clay, which is decomposed feldspar, is made in putty with water or glycerine; the latter preven its getting hard for a considerable time.

Almost the only tools required for modelling made of box-wood with variously shaped ends. handles are about 6 inches long; the sharpest e are slightly nicked; the others are all more or blunt.

A horizontal lathe or turning table, like a pot wheel, is also used for circular pieces.

A few nicely-planed boards, of various sizes,

required. On these boards an outline of scroll or other work is drawn, the clay being placed thereon and modelled.

Clay is modelled with the hand and wood tools, mostly by pressure. The clay adheres to wood, or the turning table, when slightly moistened, and requires no other fixing.

Models made either in clay or wood, and which are intended for immediate use, require to be made larger than the size given, by $\frac{1}{4}$ inch to every foot.

Brass castings under 12 inches in size shrink about $\frac{1}{8}$ inch to a foot in the mould. Large castings shrink about $\frac{3}{16}$ inch. For this purpose it is best to construct a measure or rule, properly divided, so as to save time and calculation.

Should it be required, however, to make a metal pattern from the clay or wood, then the shrinkage will be double, and the model will require to be made $\frac{1}{2}$ inch larger per foot every way, a second measure or rule being required. The real shrinkage is only $\frac{1}{8}$, but the other $\frac{1}{16}$ is allowed for finishing. Patterns exactly rectangular do not draw well from the sand; hence, all patterns should be made with a taper of at least $\frac{1}{8}$ inch to every foot. Sharp internal angles should be avoided, as they leave an arris on the sand which requires mending.

corresponding with the pins and snugs of the moulding boxes. The pins of the moulding boxes may be either simply faced, or steel fitting strips can be inserted into grooves formed in them by mandrels.

When an opening or hollow has to be left in the interior of a brass casting, a core is inserted in the mould. This consists, as usual, of a properly shaped piece of baked sand, exactly the counterpart of the hole that is desired. This is placed in the mould to prevent the metal or alloy from running into the space. To keep the core in its position, it is made a little longer or wider than necessary, so as to have a bearing to rest on at each end. The pattern must have projections on it, so as to leave an impression in the sand to receive the end of the cores. Some cores have only one bearing, as in the case of undercut work, such as fluted columns and ornamental scroll-work. Innumerable modifications in the size and shape of cores exist in every-day practice, and much skill is required in their preparation.

Cores are usually made in boxes. Where it would be too costly to construct a core box, it may be dispensed with by moulding the pattern in sand and casting it solid. A good composition for this purpose is 1 part of plaster of Paris to 2 parts of brick dust, mixed with water. When cast and dry, scrape down to the form of the

Cores, like moulds, must have passages in them to allow of the escape of gases, otherwise the casting will almost inevitably be spoiled. A wire must be inserted in the core to make such vent, and be withdrawn just before opening the core-box to remove the core. When cores are large they are supported with iron rods, round which they are built up. To give consistency to the sand used in making cores, about one-half of it should be pure rock sand, which contains a certain amount of clay, but not generally enough, and consequently the addition of clay water is necessary to give the sand cohesiveness.

The cores must be dried in a stove, at a temperature not exceeding about 400° F. When dry they should be black-washed, or coated with a mixture of ground charcoal and water, with a little size. This wash must be dried in the stove, when the cores are ready for use. In green sand moulds it is advisable not to insert the cores till just before pouring, so as to prevent their absorbing moisture.

When a thin brass casting is required, the upper half of the mould is moulded from the opposite impression, and a thin packing piece of clay or other material is placed between the two boxes to keep them the required distance apart. When it is desired to mould smal animals, butterflies, leaves, or

other delicate and intricate objects which can be consumed by fire, they are suspended in a box surrounded with a mixture of 2 parts of brick dust to 1 of plaster of Paris mixed with water. This mould is placed in a furnace to consume the pattern, the remains being shaken out as far as possible, and the metal poured.

Brass is usually melted in the air crucible furnace, but when large castings are made, as those required for marine engine work, or for ecclesiastical furniture, a reverberatory furnace will be found most suitable.

Brass founders' air furnaces are most frequently sunk below the floor level, the ash-pit being closed with a hinged iron grating. The covers for the furnace top may be either of cast or wrought-iron, and should be of a dome shape; there should be a damper in the flue. The interior of the furnace must be lined with fire-bricks set in fire-clay.

The fire-bricks and clay are often contaminated with foreign matters, such as oxide of iron, magnesia, lime, or black-lead. These impurities impair their fire-resisting qualities, and very much shorten the "life" of a furnace. Pure clay should be white, opaque and oily to the touch, and on analysis should be found to contain a large percentage of silica and

alumina. Fire-bricks are made from this clay in the ordinary manner.

It is also most important to have good crucibles, which will neither corrode nor allow liquids and gases to pass through them. They should also be capable of resisting sudden changes of temperature. The crucibles used are either made of black lead or clay. The latter are cheaper, but less durable than the black lead, and require to be carefully hardened by a gradual exposure to high temperatures.

In mixing and pouring brass the least volatile metal should be melted first, the others being plunged under the melted metal with tongs, in small lumps, which must be hot and quite dry. The reason that the metal should be hot is that it may remain dry, as the steam from any slight moisture on it when placed in the melting pot, would probably send the melted metal spirting about in all directions.

The fuel for the brass furnace is hard coke, which is broken up into lumps the size of a man's fist. The crucible is placed bottom upwards in the fire, so as to get it thoroughly heated; it is then removed with the tongs, turned right side up, and bedded on a slab of fire-clay or a fire-brick, covered with its lid, and the fire neatly banked up around it. The metal is then placed in the crucible, the cover put on the

mouth of the furnace, and the damper is opened to increase the draught. The crucible then remains until the metal is "down." It is usual to throw in with the metal some charcoal dust or broken glass, which floats on the surface of the molten metal and prevents oxidation. In feeding the metal into the crucible, put in the copper or old brass in small pieces until it is nearly full. When this is well melted, add the tin and mix it well in; then throw in a few small pieces of zinc. If the zinc flares up, throw the rest of it into the pot, stirring it well; then lift the pot from the furnace, skim off the dross, and pour into the mould.

When placing the zinc in the crucible, drop a piece of borax as large as a walnut into it. This is done to prevent the loss of zinc which goes off in the fumes. If the surface of the metal is covered by fine charcoal or borax, which is prevented from burning by being renewed, or by broken glass, the loss of zinc is reduced to a minimum.

If, however, when the small trial pieces of zinc are thrown in, they do not flare up, throw on a little fuel to make the fire brisk, and cover it over until it comes to a proper heat. Then, as soon as the zinc begins to flare, add the rest. If old brass alone is melted no tin is required, but a small quantity of

zinc. If part copper and part brass, add tin and zinc in proportion to the new copper, with a little extra zinc for the brass. To prevent volatilization, char coal or broken glass may be spread over the metal while being melted.

If the metal is poured too hot, the casting will be sand-burned and its color impaired. The best cast ings are obtained when the metal is at such a temper ature that it will cool quickly. Heavy castings should, therefore, be poured last. The metal must be carefully skimmed. Small work is poured verti- cally, large work horizontally.

As soon as the brass is poured, it is usual to open the boxes, and to sprinkle the castings with water from the rose of a watering-pot, which makes the castings softer than they would otherwise be. When the casting is completed, let the fire-bars drop, clear the furnace from ashes and clinkers, and place the po amongst them to cool gradually.

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For *facing sand* a mixture of potato starch and charcoal dust or fine white flour is used; but charcoal dust is the favorite material.

Sand cores are used for all hollow pieces, unless they are to be cast in loam, or are of a large size; in the latter case, the cores are of loam. In bronze statue casting, the thickness of the metal should be as uniform as possible, otherwise the work will be distorted from unequal contraction; bronze contracts considerably on cooling, the extent depending on the proportions of the constituent metals employed in its composition and varying from one to two per cent. This contraction is found to increase in ratio with the size of the casting.

The perfection of bronze casting is said to consist in having the mould very highly finished, and obtaining a bright sharp casting, which shall require only a minimum amount of subsequent chasing and tool-work, thus leaving the skin of the casting as far as possible undisturbed.

In the French fine-art work the furnace arrangements are such that the moulds and cores are generally dried in furnaces heated by the waste heat from the crucible furnaces. The bronze is melted in clay crucibles, holding between 60 and 70 lbs., with coke for fuel, and a fan-blast. For large work an air furnace is generally employed.

English or Straits tin, and very pure South American copper, which latter is purified by liquation, are the metals employed. A proportion of gates and runners may be added, but this is only done when the proportions and quality of their ingredients are known; and no old bronze guns, old copper or brass, or other material of unknown and variable composition, are ever used, as it is considered impossible to rely upon obtaining a first-rate casting from such uncertain ingredients.

The moulds are placed in cast-iron boxes, which are placed in a naked pit. A reservoir formed of sand with a charcoal facing is employed, into which the contents of the crucibles or air-furnaces are drawn. This reservoir communicates with the main gate of the mould, and as soon as a sufficient quantity of metal is in the reservoir, an iron plug in the bottom is removed and the metal flows into the mould, from whence the surplus passes off by "rising heads," which are purposely kept small for fear of distorting the casting by too great a pressure. The gas evolved during the pouring is fired at the rising heads by a torch.

Bronzes which are to be coated with enamel have their surfaces specially prepared for its reception by what the French artists call *cloisonné* or partition

work. This process is a somewhat tedious one, and requires great skill on the part of the moulder. The outlines of the design for the enamel are described by small thin partitions of bronze projecting upward from the main body of the work less than a twenty-fifth part of an inch. Thus the bronze has its surface covered with a network of fine lines, and when the enamel is baked into the shallow cells so formed, the enamel and the bronze partitions are ground and polished to a uniform depth. These partitions serve two useful purposes; they describe the outlines, and they tend to hold the enamel firmly in position. In finishing patterns for this class of work, every irregularity in the cells and partition walls has to be cut out, and great care is necessary not to injure the surface. When such patterns are finished they represent a considerable value in skilled labor, and are extremely delicate; consequently they are kept covered up on soft cushions, away from danger of accidental damage.

The founding of statues is certainly a very ancient branch of the art, and one in which our ancestors have held their own, as the grace and skill of existing specimens abundantly testify. The invention of the Samian artists consisted, in all probability, of running the metal into a mould which contained a centre-

piece or kernel, to diminish the thickness of the metal by leaving a hollow space in the centre of the statue. The necessity of this kernel is self-evident, for a solid bronze statue would be most costly and cumbersome. Besides, unless the statue is very light, it would in many cases be unable to stand. A rearing horse, for instance, could never be upheld by its hind legs if the whole body was composed of solid metal; and to lessen the weight that would otherwise bend and break so slender a support, it is not only necessary that the horse should be hollow, but it must be as light as skilled workmanship can render it. Since the day, therefore, of the Samian artists down to the present time, it has been the constant effort of bronze moulders to lessen the thickness of their statues by increasing the size of the kernel, so as to leave as small a margin as possible for the metal to run down this centre-piece and the mould with which it is enveloped.

Among early methods for obtaining this end, the most familiar is known as the cire-perdu, or waste-wax process, which was still in vogue when the present system was introduced, and a comparison between the two will best illustrate the progress now accomplished. The "cire-perdu" process required great care, and could only be carried out effectively

by the sculptor or modeler himself. Thus, let us suppose for the sake of simplicity that the object to be reduced is a portrait bust measuring 4 inches in height and 3 inches in width. The first step would be to model in "sand," or a mixture of porous cement, the outline of the bust, taking care to make it on every side ¼ inch smaller than the size it was designed to give to the finished statuette. This outline or "core" must be coated up with wax to make up the deficient ¼ inch. This much might be accomplished by an ordinary workman, but for the rest the services of the artist are indispensable. With great delicacy of touch he must work up the likeness and texture of his subject on the wax, in fact the expression, the minute lines, all the details of the artist's conception, must be executed in this wax, and it will be seen at once that he alone is competent to carry this out satisfactorily. Were it done by anyone else, it would be at the best but a copy of the artist's conception.

The portrait completed, five or six pieces of wire must be pushed through the wax into the sand outline or core. It is now necessary to coat over the wax with liquid sand, applied most carefully with a fine hair-brush. When a few coats of this sand have been made to adhere to the wax, the statuette

is surrounded by an iron frame, and the frame is filled up with sand-mixture. The frame is generally twice the size of the statue. When all is ready this frame is removed with its contents to a warm place, so that the water may evaporate from the sand, and the latter gradually consolidate. Holes must then be cut at one end through the outer sand, after which the frame is subjected to the baking process in a hot oven. The wax of course melts and runs out of the small perforations, leaving a space between the inner core, maintained in its position by the wires above mentioned, and the outer mould, which latter bears the faithful impression of the modeling bestowed on the wax. The holes through which the wax escaped are now used for the purpose of introducing the molten bronze. The metal poured in rapidly fills the space once occupied by the wax, and the work is done. When the metal has had time to cool, the artist anxiously breaks the sand-casing away to disentomb his work. Sometimes a successful result rewards his pains, but the work is often a failure. The metal has not perhaps filled all the sharper and smaller crevices in the mould, or the presence of damp has impeded the process, or again, the escape of various gases has split the mould, and thus the whole work is in one moment destroyed, and must be recommenced from the very first stage.

On the other hand, the method now pursued is more scientific, involves less risk, and is consequently less expensive, though it is still necessary to exercise the greatest skill and judgment. The sculptor need only produce his conception in plaster, and when this is finished, hand it over to the founder, who can undertake the rest of the work without any assistance from the sculptor. The plaster model is immediately imbedded in the sand contained in an iron frame or moulding box. Thus safely laid out in a soft bed, the workman begins what is called piece-moulding. Taking a small section of the statue, he forces the sand, by striking it gently with a mallet, into every fissure and crevice, and thus obtains an accurate impression of that part of the model on which he has been working. Having completed one piece he proceeds with another, until by putting the pieces together, he can cover that part of the statue which is exposed outside of the sand box. The model is then lifted from its bed, turned round, impressions taken from the other side, and when this is completed the model can be removed uninjured.

The pieces of sand having the impressions of the model are fitted together in their relative seatings within the two halves of the mould-box. The mould being removed, we have, as it were, two sand-

inversions, one representing the right and the other the left side of the statue. The moulder then proceeds to make in the impress, a core or fac-simile, only a little smaller in size, so that when this is placed within the mould, there should remain all round a margin between the mould and the core equal to about $\frac{3}{16}$ inch in thickness. The core and the pieces which constitute the mould being secured in their respective places, the whole is then exposed to the heat of an oven, so that the moisture may be removed and the sand hardened to receive the metal. Vents for the foul air and the gas must also be provided, and runners to enable the metal to penetrate rapidly the margin between the core and outer mould after the bronze has thus been cast. The sculptor may, if he chooses, suggest any improvement to the chaser, who polishes and finishes off the casting. Owing to the intricacy and fineness of the model, it sometimes requires a great number of pieces to make the mould, and several months' work to finish successfully, even a group small enough to be stood upon a mantle-piece. One of the great advantages of this new process is the fact that if the casting fails, the artist's model, the result perhaps of infinite labor and of an inspiration which may never be repeated, remains unaltered. A new mould may be taken from it, and the second cast prove a succes

The statue may thus also be reproduced as often as desired; while with the old process, the artist's work was carried away for ever as the wax melted, and if the cast proved a failure, there was no longer any record of the work done and lost.

BELL-FOUNDING.

BELL metal is best composed of 80 parts copper and 20 tin, or 78 parts copper and 22 tin. There are, however, variations from these proportions, and small accidental or intentional admixtures of zinc, lead, etc., for instance, 71 parts copper, 26 tin, 1.8 zinc, and 1.2 iron, or 80 parts copper, 10.1 tin, 5.6 zinc, and 4.3 lead. As regards silver, that is a purely poetical and not a chemical ingredient of bell metal, there being no foundation whatever for the popular notion that it was commonly used in old bells, nor the least reason to believe that it would do any good. This may readily be judged from the fact that a silver cup makes rather a worse bell than a cast-iron saucepan.

For *house bells* the following proportions may be recommended: Copper, 4 parts; tin, 1: for *tower bells*, copper, 32 parts, tin, 9; and for very *large tower bells*, copper, 16 parts, and tin, 5.

According to Lafond, the following mixture is suitable for bells, but especially for small bells and piano plates: Copper, 77 parts; tin, 21, and antimony, 2. This yellowish-white alloy can be filed only with difficulty.

Experiments have been made to ascertain whether there is any other metal or alloy which would answer better, or as well, and be cheaper than bell metal. The metals that have been suggested are aluminium, either pure or alloyed with copper, cast-steel, union metal, consisting of tin and iron, and perhaps glass might be added. The first is at present quite out of question, as it is too expensive. Steel bells, though they might be made cheaper than those of bell metal, are exceedingly harsh and unpleasant in tone. Much the same may be said of the iron and tin alloy of which there was a large bell in the London exhibition of 1851. It is scarcely necessary to refer to glass, because its brittleness is enough to disqualify it for use in bells, but besides that the sound is very weak compared with a bell-metal bell of the same size, or even the same weight and, of course, much smaller.

Dr. Percy cast several small bells of various alloys with the following results:

1. Iron 95, antimony 5. Not as good as copper-tin alloy either in tone or strength.

2. Copper 88.65, phosphorus 11.35. A very hard alloy, capable of a fine polish, but more brittle than bell-metal, and inferior in sound even to the iron alloys.

3. Copper 90.14, aluminium 9.86. This exceeds bell-metal in strength and toughness, and polishes like gold, but for tone it will not stand against bell-metal.

4. Brass. This makes a better bell than the last-named alloys, but very inferior to bell-metal.

M. Saint Claire Deville, of Paris, cast a bell of pure aluminium. In form it was a reproduction on a small scale of the Westminster bell, reduced to 6 inches diameter. The surface was turned and every care taken to produce as perfect an aluminium bell as possible. But this proved quite as objectionable in tone as any of the alloys above named, whilst of course the cost would have put the metal out of question commercially, even if it had given a good musical result.

For the construction of large bells, it is of importance to know the constituent parts of a bell. Every bell consists of the lower rim, the prim, pinch or sound-bow, i. e. the thickest part upon which the clapper strikes, further the interior sloping cavity, the curve, where the bell gradually becomes thicker

and wider, the upper half, the neck above the cavity, the cap which closes the bell above and carries the clapper, and the crown which is cast on the cap. The prim or pinch determines the proportion of the entire bell. For 200 lbs. of bell-weight, 8 lbs. of clapper-weight are, as a rule, allowed. The strength of the sound is dependent on the quantity of metal, and its depth on the form of the bell. To a complete church peal belongs the octave of tones: the principal notes or key-notes, deep and high, then the fourth and third; hence, four bells. The relation of their diameters is as that of the figures 2, $1\frac{3}{5}$, $1\frac{1}{3}$ and 1, and the magnitudes of their weight as 8: $4\frac{1}{10}$: $2\frac{1}{10}$: 1.

In bell founding a distinction is made between the casting of small and of large bells, and both kinds will here be discussed.

I. *Moulding and casting of small bells.* Small bells are generally moulded in sand. The patterns used are usually of tin, and must be accurately and correctly made as regards the proportion of width and height, as well as the thickness of the metal to the tone which the bells to be cast are to possess. The patterns have no crown or clapper-ring, but instead of them are provided in the centre of the cap with an oblong rectangular aperture.

Moulding is done in flasks or boxes, which generally consist of three cast-iron or cast-brass frames placed one upon the other. Wooden frames are seldom employed. For the process of moulding two moulding boards of pine, or best of linden wood, are required for each flask. During casting, they also serve for covering the outer open surfaces of the sand mould and, hence, form, so to say, movable bottoms of the flasks. They should be somewhat longer and wider than the flasks to which they belong, and be nicely planed on one side, and, to prevent warping, provided, on the other, with cross pieces.

The process of moulding the patterns in sand is as follows: Lay the bell-pattern upon a moulding-board, place one part of the flask over it, and fill it with moist sand. Then invert this portion of the flask so that the pattern now appears as if sunk from above in the sand, dust the latter with powdered charcoal, then place the other portion of the flask upon it and fill it also with sand. Or proceed in the reverse order: Fill the lower portion of the flask with sand, place the pattern upon or sink it somewhat in the sand, and proceed with the upper portion as before. The object of dusting the sand with charcoal is to prevent the adhesion of the two masses of sand con-

tained in the two portions of the flask. However, any charcoal powder which may have fallen upon the pattern must be removed, in order to give the sand a chance to penetrate into the depressions. The sand is then carefully and firmly pressed down with the hands, the flask entirely filled with sand, and the latter leveled with an iron straight-edge. Moulding being finished, the flask is parted, the pattern carefully lifted out, and the gate arranged. Small bells are moulded in an upright or inverted position, or rather the process of moulding remains the same, but the runner is placed in two different ways, either from the crown side or from the side of the sound bow.

a. *Moulding the bell in an upright position.* In this mode of moulding, the upper part of the flask must have the same height as the bell together with the quoin, whilst the under part may be lower. The upper part is placed upon a moulding-board, and, after placing the bell-pattern together with the quoin in it, the space around it is filled with sand. The flask is then inverted, so that the mouth of the bell is upwards. The under part of the flask is next placed upon the upper and rammed full of sand, which at the same time fills the interior of the bell, and thus forms the core. Before ramming in the

sand the iron staple for the clapper must be so placed in the cavity that only its ring projects, which is then enveloped by the sand of the core. When this is done the flask is again inverted, the upper portion lifted off, the quoin drawn out, and, after taking the pattern from the core, the flask is again put together. Casting is effected through the aperture left by the quoin. The sides of the staple for the reception of the clapper are then in the empty space and sur rounded by the casting. The high gate is also filled up in casting, and the bell appears with a tenon of the form of the removed quoin sitting upon it. If the bell is to be provided with a ring screwed into the crown, this tenon is sawed off, or a portion of it sufficient for securing the bell is allowed to remain.

This mode of casting bells has often the disadvantage that the core is readily injured by the metal flowing in, and that the latter, since it must spread in all directions from one gate, cools off rapidly, and frequently does not completely fill the mould. For this reason moulding in inverted position is preferred.

b. *Moulding the bell in inverted position.* The bell pattern is placed upon the moulding-board inside the under part of the flask and entirely surrounded with sand. The flask is then inverted, and the upper portion placed upon it. Three small rods runn

loosely together to a knob over or outside the mould are moulded in, the upper part of the flask being at the same time filled with sand, whereby the core is formed. Around the knob a funnel-like depression for pouring is made. Before taking out the pattern the rods are withdrawn, the passages formed thereby serving as gates. If the bell is to be provided with a canon, a cavity is made in the sand by means of a flat piece of wood. The staple for the clapper is put in in the same manner as before described. By this mode of casting the metal flows in from the gate through three passages, and rapidly fills the mould from three points without injury to the core.

II. *Moulding and casting large bells.* In the construction of large bells, it is of great importance to know the proportions between the dimensions which are most advantageous for the production of sound. The principal conditions for a good bell are:

1. The greatest diameter of the bell must be at the mouth, and the greatest thickness of metal at the sound-bow.

2. A bell should at the utmost measure in width fifteen times and in height (measured obliquely on the outside) twelve times the thickness of the sound-bow.

3. The thickness of the bell decreases from the

sound-bow up to half its height and from there on should amount only to one-third of the thickness of the sound-bow. From the sound-bow to the circumference of the mouth the thickness also decreases.

4. The diameter of the mouth of the bell should be twice as large as that of the uppermost part of the crown.

5. The weight of the clapper should be about $\frac{1}{40}$ that of the bell. For very large bells a weight of 5 to 10 lbs. may be added to the clapper.

6. The ball of the clapper, i. e. its round or pear-shaped end, should be thicker in the proportion of 5 : 3 than the thickness of the metal on the sound-bow. However, this applies chiefly only to bells weighing over 120 lbs.

The correct profile of a bell of given diameter is traced in the following manner, small variations being, however, customary in many foundries. Suppose the horizontal line *a b* in the accompanying illustration (Fig. 1) is the prescribed width of the bell at its mouth. Divide this line which for this purpose is once more drawn at *a' b'*, into 15 equal parts, which are called "prims," because one such part represents the thickness of the bell on the prim or sound-bow. The diameter of the bell thus divided serves as a measuring scale in the following operations. Fir

divide $a\ b$ by the lines $c\ f$, $d\ g$, and $e\ h$ into four equal parts; $f\ h$ now gives the diameter of the cap, which is one-half the diameter of the mouth. Now measure off with the compasses twelve prims, and with the distance thus obtained intersect from the point e the line $e\ h$ in i, then draw the line bi, and divide it into 12 equal parts; with the radius $b\ k$, which is equal to $1\frac{1}{2}$ prims, describe an arc from b. By now cutting off a prim from k to l, the thickness of the bell on

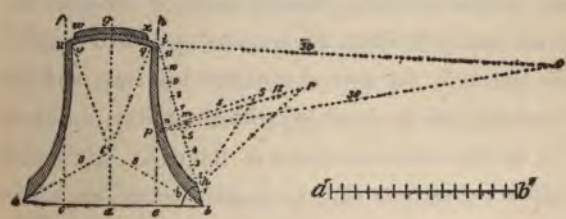

FIG. 1.

the sound-bow is obtained. After drawing the line $l\ b$, erect upon m, as the centre of $b\ i$, a perpendicular, and set off upon it a piece, $m\ n = 1\frac{1}{2}$ prims. The point n determinates how far the curve of the bell recedes in the centre of the height. The curve itself consists of two parts, $n\ k$ and $n\ i$, of different curvatures. To trace it, find with a distance of 30 prims from n and i an intersecting point o, and from there describe with the radius $o\ n$, the arc $i\ n$.

Further set off upon the line *m n* from *n* to *p* ⅓ prim, and describe from *o* with the radius *o p* the arc *p q* for the interior curve of the upper half of the bell. The interior curve of the lower half has to be drawn from another centre. For this purpose find with a distance of 12 prims, from the points *p* and *l*, a centre *r*, and describe from it the arc *p l*; then from the points *n* and *k* find, with a distance of 8 prims, a point *s* which gives the centre for describing the arc *n k*. Finally, with a distance of 8 prims intersect from the terminal points *a* and *b* of the line *a b*, the axis *d g* of the bell in *t*, and from the latter point, describe with the radius *t i* the arc *i n* for the outer curvature of the cap. The cap receives a thickness of ⅓ prim, and, hence, its internal curvature is described from the centre *t* with a radius which is ⅓ prim smaller than *t i*. For the better securing of the crown upon the bell, the thickness of the centre of the cap is increased by ⅓ prim, which is designated by *w x*. The exterior shape of the bell traced according to the above described rule is frequently subject to small variations, for instance, by rounding off *i*, and *u* on the edge of the cap, as well as *k*, and by hoops and rods arranged in different places on the surface, partially for the sake of increasing the strength, and partially for ornamentation.

From what has been said it will be seen how difficult the construction of bells is, and that every part must be strictly cast in accordance with its proportions. If bells of a fixed weight are to be cast, a normal bell of known tone, dimensions, and weight is used for the calculation. However, such calculation is not applicable to very large bells, and, hence, they must be constructed according to the above described proportions. Though the moulding of large bells may be called a master-piece, the casting requires the same attention and equal skill, in order to obtain a pure harmonious tone; the slightest inaccuracy or defect in casting destroys the harmony, and spoils the bell.

In calculating the sizes of bells to produce particular notes, and assuming that eight bells are made of similar material and their sections exactly similar figures in the mathematical sense, they will sound the eight notes of the diatonic scale, if all their dimensions are in these proportions: 60, 53⅓, 48, 45, 40, 36, 32, 30, which are merely convenient figures for representing the inverse proportions of the times of vibration belonging to the eight notes of the scale. So that if it is required to make a bell a fifth above a given one, it must be two-thirds of the size in every dimension, unless it is intended to vary the

proportion of thickness to diameter, for the same rule then no longer holds, as a thinner bell will give the same note with a less diameter.

The weights of bells of similar figures vary as the cubes of their diameters, and may be nearly enough represented by the figures 216, 152, 110, 91, 64, 46, 33, 27. The exact tune of a set of bells, as they come out of the moulds, is a secondary consideration to their tone or quality of sound, because the notes can be altered a little either way by cutting, but the quality of the tone will remain the same forever, except that it gets louder for the first two or three years that the bell is used, probably from the particles arranging themselves more completely in a crystalline order under the hammering, as is well known to take place.

The usual mode of hanging bells is to cast six ears or loops on the top or crown of the bell; these are called *canons*, through which iron hooks and straps are put to fasten the bell to the stock.

This method of hanging by canons is no doubt objectionable, as they must always be the weakest part of the casting, from being nearest the top, and in practice it is found that they frequently break and have to be replaced by iron bolts put through holes drilled in the crown. It is also difficult to turn the

bell in the stock, to present a new surface to the clapper when it is worn thin in one place. In some bells these disadvantages are avoided by casting a very short, thick, hollow neck with a strong flange round the top, which can be fastened to the stock by bolts with hooked ends. By this arrangement the bell is held by a large section of its own metal, and can at any time be shifted round by slackening the bolts. If a clapper is to be used, it can be hung upon a separate bolt passing through the hole in the neck and through the stock, and secured above.

When only clock hammers are employed to strike on bells, the wear is so small that the facility of turning the bells is of secondary importance. This plan has the recommendation of great strength, and would probably have been largely adopted but for the loss of the *canons*, which are regarded by the founders as an ornamental finish to bells, upon which they rather pride themselves.

Before the Reformation it was usual to cast some religious invocation on the bells; that custom was replaced by the founders placing their trade marks, or some short sentiment or verse, upon the bells, either with or without a date.

a. *Moulding large bells.* Large bells are moulded in loam in the foundry-pit located immediately in

front of the furnace. The loam used should be pale, meagre, and free from coarser pieces of sand and stone. For the core, as well as for the interior of the cope, it should be passed through a fine sieve. On the other hand, red fat loam is used for making the outer layer of the mould, it possessing greater cementing power. For constructing the mould the loam is mixed with horse-dung, straw, chaff, or plasterers' hair, and wetted with water so that it can be kneaded and readily applied.

In the centre of the foundry-pit a post designated *c*, in the accompanying illustration, (Fig. 2) is driven into the ground.

Around this post a wide platform of bricks is built, upon which the core is erected in brick. This core is hollow and, to enable the workman to make a fire in it, is provided below with the flues *e e* for the necessary draught. About half the height of the core, a flat iron rod *g* is laid upon the post *c* and bricked in the wall of the core. In the centre of this bar is a hole for the reception of the point of the spindle *h*. The latter is provided with two fork arms *k*, between which the pattern or templet is secured by means of screws. This templet *A* is a board of hard wood cut in the shape of the interior form of the bell, the edges being covered with

brass or zinc. The templet serves as a guide for obtaining the correct curve in building up the core. When the core is finished one workman covers it with loam, while another removes any excess of loam

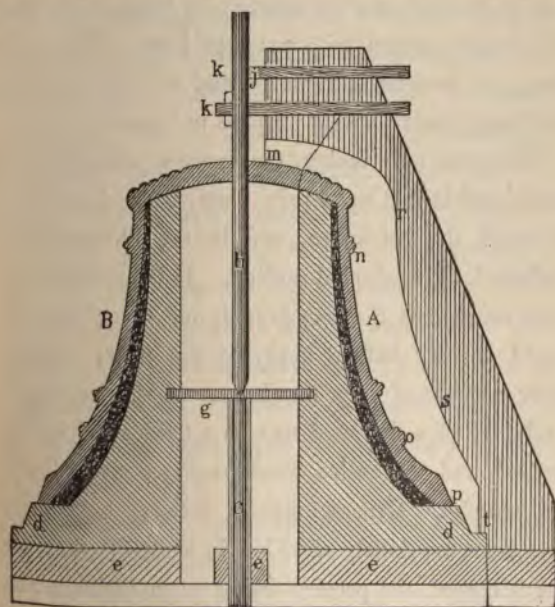

Fig. 2.

by turning the templet. The last surface washing is given by a finely-ground composition of clay and brick-dust.

In moulding a bell, the loam should be applied in

layers and one layer allowed to dry before applying the next. To give, on the one hand, the core a smooth surface, and, on the other, to insulate it from the adjoining layer of loam of the "thickness," it is finally brushed over by means of a brush with finely sifted ashes mixed with water or beer. This being done, the templet is removed and the core dried, a fire being made for this purpose in its cavity.

When the core is dry, the layer representing the actual bell is laid upon it in loam sand. This layer is called the *thickness*, and in the illustration, is indicated by a stippled outline. It is applied in the same manner as the core-layers, one layer being allowed to dry before applying the next: the last layer is made of very fine loam. A thin coating of a mixture of tallow and wax in a fluid state is then applied, and the entire mould again compared with the templet. Ornamentations, letters, etc., which have been previously moulded in modelling wax, are now attached, the process being much facilitated by the above-mentioned coating of tallow and wax.

The moulding of the cope is next proceeded with. Since the cope has to stand a strong pressure from the interior to the exterior, it must be of sufficient thickness—for large bells at least 5 to 6 inches—and somewhat thicker on the bottom than on the top. In

building up the cope, different kinds of loam are used. The first layers are made of fine, sifted loam mixed with moulding sand or brick dust, and made into a paste with sifted horse-dung and water. This paste is carefully applied with a brush, so that all depressions in the ornamentations, letters, etc., are well filled up. These thin layers must be allowed to thoroughly dry in the air. Upon this coating is laid ordinary moulding loam applied either with the hand or trowel. After applying the first layer, a fire is kept up in the core, whereby the coating of tallow and wax melts and soaks in the loam mould, leaving an empty space so that the cope can be readily lifted off. The last layers of the cope are made of loam mixed with plasterers' hair, and in order to prevent tearing, hemp ropes are frequently kneaded in all around.

The crown of the bell is moulded over a wood pattern after the spindle is removed. The iron or steel staple for the hammer is set in the core in the hollow left by the spindle. It projects into the thickness so as to be cast into the metal.

When the cope is finished, it is secured by iron hoops and rods, which are screwed together, and form, so to say, an iron frame around it. The cope is then lifted off with the assistance of a crane

or tackle, accurate marks having previously been made to serve as guides for its replacement. The cope having been lifted off, it is repaired, if necessary, with the above-mentioned mixture of loam and moulding sand or brick dust made into a paste with sifted horse-dung and water. It is then dried and heated to glowing to prepare it for casting. The thickness upon the core is now carefully removed with hammer and chisel. The core is then again revised, and, if necessary, repaired, and finally given a uniform coating of the previously mentioned mixture of ashes with water or beer. The cavity of the core may be filled with sand, if preferred, but there is no harm done if it is left open; for bell-metal does not generate much gas, and there is no danger of an explosion. The core being thoroughly dried and warmed by a fire made around it, the warm cope is placed over it, and after putting the mould of the crown in position, all the joints are carefully closed with loam. The mould of the bell being now finished, the pit is filled with sand well rammed in. The cast-gate is on top of the bell, or, if the latter is ornamented, on one side of it. Flow-gates are of no use here; the metal must be clean before it enters the mould.

D. *Casting large bells.* In casting large bells, a

reverberatory or air furnace is used for melting the metal. The furnace consists of two principal parts, separated from each other, viz., the fire-chamber and the bed or hearth. In the first, the fuel is burned, and in the latter, which is round or oval and slightly depressed, the metal, spread out in not too high a layer, is melted. Opposite to the fire-chamber in the front wall of the furnace is the tapping-hole, closed from the inside by a plug, which is pushed in when the metal is melted.

In casting bells it is a rule to melt the metal as rapidly as possible and keep its surface covered with powdered coal or coke. First melt the copper, and when that is perfectly liquid add the other metals. When adding the tin, endeavor to push it down to the bottom of the melted copper, otherwise a considerable portion of it will volatilize and burn before combining with the copper. When the metal is melted, a sample is taken out with a ladle, cast in sand, and examined as to grain and fracture. If the mixture proves successful, the melted metal is freed from impurities and casting may be proceeded with. If instead of new metal old bell-metal is to be used, a sufficient quantity of new bronze (copper and tin) to make up the loss in the old bronze has to be added. For melting 4 to 8 hours are required, ac-

instead with levers over the furnace. Many bell-founders have also furnaces with simple flues in the vault without chimney, but they are not suitable for large castings.

The principle of the reverberatory furnace is so to deflect, or direct, the currents of flame and heated air that they may exert their most intense power upon the metal lying on the bed of the furnace, in which respect the air-furnace somewhat resembles the action of the blow-pipe, with which the greatest concentration of heat on a certain body can be effected in the least time.

The casting being completed, it is allowed to cool 12 to 24 hours. The pit is then emptied, the cope removed, and the bell lifted from the pit with the assistance of a crane or tackle. It is then transported to the work-room, where the feeding-head and vent-hole pieces are sawed off, the letters ground and the ornamentations chased, or, with ordinary bells, simply rubbed with sand-paper.

Repairing cracked bells. Cracked bells, if it is not preferred to recast them, may be repaired by filling up the crack, or if it does not extend beyond the sound-bow, by cutting it out. However, bells repaired in this manner never possess their original pure and beautiful tone, and are not very durable.

The operation of filling up the crack is as follows: Saw or file the edges of the crack so as to form an empty triangular space. Into this space accurately fit a piece of wood, which serves for the preparation of a mould, in which the piece of bell-metal to be set in is cast. Then fill and surround the bell with glowing coals so that as uniform a heat as possible is maintained, care being, however, taken to prevent the melting of the bell. After 10 to 12 hours direct the blast only upon the crack, lay the piece to be set in, which has been previously cast, in the fire, and, when it and the edges of the crack are nearly at a white heat, remove the coals and ashes, scatter borax upon the edges, place the piece in the crack with the assistance of tongs, and drive it in by gentle blows of the hammer. By hammering, the heat of the edges is sufficiently increased to cause them to fuse together with the new piece. The bell is then allowed to cool slowly, when the crack is filed smooth.

Weight of a few peals of bells. The following scale gives the average weight of a few peals of bells, of such sizes and proportions as are recommended by Messrs. Warner and Sons in their "Notes on Bells:"

Peals of 3.						Peals of 6.					
Weight of tenor.			Note.	Weight of peals.		Weight of tenor.			Note.	Weight of peals.	
cwt.	qrs.	lbs.		cwt. qrs. lbs.		cwt.	qrs.	lbs.		cwt. qrs. lbs.	
3	1	0	F sharp.	8 1 0		9	2	0	B flat.	35 0 0	
3	3	12	E.	9 2 14		10	2	0	A.	40 0 0	
4	3	0	E flat.	12 0 0		11	2	0	G sharp.	42 0 0	
5	1	0	D.	13 2 0		13	2	0	G.	50 0 0	
6	2	0	C sharp.	15 0 0		16	0	0	F.	60 0 0	
6	0	0	C.	16 2 0		18	0	0	E.	65 0 0	
Peals of 4.						Peals of 8.					
5	0	0	E flat.	16 0 0		13	2	0	G.	60 0 0	
5	1	0	D.	17 0 0		15	0	0	F sharp.	68 0 0	
6	0	0	C.	19 2 0		17	3	0	E.	75 2 0	
10	0	0	A.	28 0 0		20	0	0	E.	85 0 0	
12	2	0	G.	36 0 0		25	0	0	E flat.	100 0 0	
15	0	0	F sharp.	42 0 0		30	1	0	E flat.	111 2 0	
Peals of 5.											
6	0	0	C.	23 2 0							
9	0	0	B flat.	30 0 0							
10	2	0	A.	32 2 0							
12	0	0	G sharp.	39 0 0							
13	0	0	G.	40 0 0							
15	0	0	F sharp.	57 0 0							

Analyses of Several Bell Metals.

	Rouen.	Gisors.	York.	Lincoln.	Westminster.	
			Old Peal.	1610	Top.	Bottom.
Copper	71.0	72.4	72.76	74.7	75.31	75.07
Tin (with antimony)	26.0	24.2	25.39	23.11	24.37	24.7
Iron	1.2	. .	0.33	0.9	0.11	0.12
Zinc	1.8	1.0	. . .	Traces	. . .	. . .
Lead	. .	0.4	. . .	1.16	Traces	Traces
Nickel	. .	. .	1.77	0.58	. . .	. . .
Specific gravity . .	. .	. .	8.76	8.78	8.847	8.869

List of Large Bells.

	Weight.		Diameter.		Thickness.	Note.	Clapper or hammer.
	Tons.	Cwt.	Ft.	In.	In.		
Moscow, 1736 } broken, 1737 }	250 (?)		22	8	23	. . . .	. . . .
Another, 1817 . .	110 (?)		18		. .	. . . .	. . . .
Three others . . .	16 to 31		. . .		. .	. . . .	$\frac{1}{11}$ of bell
Novogorod	31	0	. . .		. .	. . . .	. . . .
Olmütz	17	18	. . .		. .	. . . .	. . . .
Vienna, 1711 . . .	17	14	9	10	. .	. . . .	. . . .
Westminster, 1856.	15	8½	9	5½	9⅜	E	12 cwt.
Erfurt, 1497 . . .	13	15	8	7½	. .	F	. . . .
Paris, 1680	12	16	8	7	7½	. . . .	6½ cwt.
Montreal, 1847 . .	12	15	8	7	8½	F	. . . .
Cologne, 1448. . .	11	3	7	11	. .	G	. . . .
Breslau, 1507 . . .	11	0	. . .		. .	. . . .	. . . .
Goerlitz	10	17	. . .		. .	. . . .	. . . .
York, 1845	10	15	8	4	8	F sharp	4 cwt.
Bruges, 1680 . . .	10	5	. . .		. .	G	. . . .
St. Peter's, Rome .	8	0	. . .		. .	. . . .	. . . .
Oxford, 1680 . . .	7	12	7	0	6⅛	. . . .	80 lbs.
Lucerne, 1639 . .	7	11	. . .		. .	G	. . . .
Halberstadt, 1457 .	7	10	. . .		. .	. . . .	. . . .
Antwerp.	7	3	. . .		. .	. . . .	. . . .
Brussels	7	1½	. . .		. .	G sharp	. . . .
Dantzic, 1453 . . .	6	1	. . .		. .	. . . .	. . . .
Lincoln, 1834. . .	5	8	6	10½	6	A	150 lbs.
St. Paul's, 1716 . .	5	4	6	9	. .	A	180 lbs.
Ghent.	4	18	. . .		. .	. . . .	. . . .
Boulogne (new). .	4	18	. . .		. .	. . . .	. . . .
Old Lincoln, 1610 .	4	8	6	3½	. .	B flat	. . . .
Fourth quarter bell, Westminster, 1857	40		6	0	5¾	B	. . . .

CHILL-CASTING.

CHILL-CASTING converts into white iron the outer skin of a casting made from certain qualities of cast iron; the depth to which this alteration extends is capable of being regulated. This white cast iron is very hard, brittle and crystalline, and scarcely differs, either in chemical or physical properties, from steel, except that it cannot be "tempered." In this case the whole, or nearly the whole, of the carbon contained in the iron is in a state of chemical combination with it; whilst in the darker irons most of the carbon is diffused throughout the mass in the form of small particles or scales.

If the cast iron contains a large portion of manganese, the amount of combined carbon may be as much as 10 per cent., but ordinary pig iron seldom contains more than 5 per cent. of combined carbon. These particles of uncombined carbon must, whilst the metal is in a melted state, be combined with it, for being of a much less specific gravity, less than half, if they were floating about in separate particles, they would necessarily come to the surface of the metal. It is, therefore, assumed that the separation of the particles of carbon takes place at the moment of solidification.

If a thin sheet of gray cast iron is rapidly cooled, it becomes whiter, i. e. a larger portion of its carbon is held in chemical combination. White cast iron may also be obtained from gray pig, by alternately melting and cooling it in the ordinary manner. When it is desired to obtain a white iron direct from the blast-furnace, the proportion of fuel is reduced below the amount usually allowed for the same quantity of ore and blast, if a good grey iron were required.

These facts explain the results which are obtained by the process of "chilling" a casting; where the skin of the casting is in contact with the "chill," it is, for a certain distance inside, converted into a hard white iron, whilst the interior of the casting will remain of the same general nature, as to color and toughness, as the pig from which it was cast. The sudden cooling of the metal prevents the combined carbon near the outer portion from separating, whereas the cooling of the inner portion of the metal being more gradual, allows it to resume its normal condition. The suspended particles of carbon, which are held in the metal near the exterior of the casting, are supposed to be forced inwards into the interior, or still fluid portion, of the casting.

All, or nearly all, the carbon in the chilled portion

of the casting is therefore in chemical combination with the metal, whilst that in the interior remains suspended as separate atoms or scales. Such is the generally accepted theory of chilled castings, which may indeed be open to objection. The practical result is, however, beyond any question.

Chill-castings are much used for portions of constructions which were formerly made of steel or wrought-iron, such as columns, shafts, material for railroads, etc. If the pieces cast in chills possessed the same degree of hardness throughout, they would, on the one hand, be difficult to work, and, on the other, be very brittle. For this reason it is sought to limit the effect of the chill to the portion of the casting which requires hardening, by making the moulds for the purpose of several parts, some of

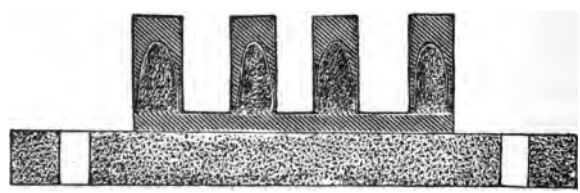

FIG. 5.

them consisting of sand and loam, which do not exert a hardening action.

Thus in casting, for instance, the tongue of a frog

for a railroad, the upper portion of the rail and tongue is only cast in chills, while the remainder, the bottom-plate, lies in a sand-mould which stands over the chill. Consequently only the upper portion of the rail and tongue (Fig. 5,) consists of chilled casting, which is converted into mottled pig, while the bottom-plate consists of fine-grained grey iron.

A few examples of moulding may here be given.

a. *A chilled roll, the journals of which are to remain soft.* The mould Fig. 6 consists of three parts. The lower box of iron or wood is filled with "new sand," or a strong composition of clay and sand, in which a wooden pattern is moulded, which forms the coupling and the neck of the roll. The middle part of the mould is the chill, a heavy iron cylinder well bored. The upper part of the mould again consists of a box, but is higher than the lower box, so as to make room for the head in which the impurities of the iron, sullage, are to be gathered. The two boxes with their contents of sand must be well dried. The chill is the important part in this mould. It ought to be at least three times as heavy as the roll which is to be cast in it, and provided with wrought-iron hoops to prevent its falling to pieces, for it will certainly crack if not made of very strong cast-iron. The iron of which a chill is cast

should be strong, fine-grained, and not too grey. Grey iron is too bad a conductor of heat; it is liable to melt with the cast. Iron that makes a good roll

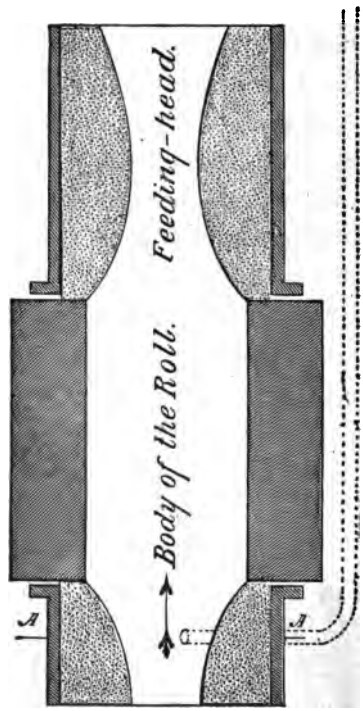

Fig. 6.

will make a good chill. The face of the mould is blackened like any other mould, but the blackening must be stronger than in other cases, to resist more

the abrasive motion of the fluid metal. The chill is blackened with a thin coating of very fine black-lead, mixed with the purest kind of clay. This coating must be very thin, or it will scale off before it is of service.

The most important point in making chilled rolls is the mode of casting them, and the quality of iron

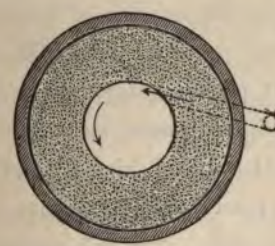

FIG. 7.

used. To cast a roll, whether a chilled roll or any other, from above, would cause a failure. All rolls must be cast from below. The dotted lines in the illustration (Fig. 6) indicate the cast-gate and channel as it is seen from above. A cast-iron pipe, lined inside with mass and thoroughly dried, is generally used. It is screwed to the moulding box for the lower journal of the roll and, as shown by the dotted lines, continues to a certain distance around the latter. Fig. 7 shows a section through the moulding box in the direction of A A. From it it will be seen that

the channel of the cast-gate touches the mould in a tangential direction. In casting fluid metal in this gate, the metal will assume a rotary motion around the axis of the roll, or the axis of the mould. This motion will carry all the heavy and pure iron towards the periphery, or the face of the mould, and the sullage will concentrate in the centre. It is a bad plan to lead the current of hot iron upon the chill, for it would burn a hole into it, and melt chill and roll in that place together. The quality of the melted iron modifies in some measure the form of the gate, stiff or cold iron requiring a rapid motion, while fluid, thin iron must have less motion, or it is liable to adhere to the chill. The roll must be kept in the mould until perfectly cool, but the cooling may be accelerated by digging up the sand around the chill.

In considering the advisability of the greater or less depth of chill, estimate the extent to which the casting may be worn or turned before it becomes necessary to replace it. For castings that will have much surface-wear, such as in rolling metal, or crushing minerals, allowance should be made in the depth of the chill for the removal of the exterior of the rolls, by their being repeatedly turned in the lathe, as their surfaces become worn or injured in use. At the same time, it must be remembered, that the

greater the depth to which the chill is carried, the more brittle is the casting. The chief strength of the casting is in its tough, unaltered metal beneath the hard, chilled surface. Hence, chilling to a greater depth than necessary should be avoided, especially in cases where strength is required in the castings to resist transverse and other strains.

In casting large chilled rolls, the moulds for the ends and necks should be of dry sand, or loam properly built up and connected with the iron chill for the roll itself. The mass of metal in the chill largely influences the depth of the chilled portion of the casting. It is necessary not only that it should be sufficient to reduce, in a few minutes, the temperature of the iron on the surface from the temperature at which it is poured—say 2500° F.—to that of solidification—say 1000° F.—when it is bright red in daylight, but also that it should be capable of absorbing the heat which will radiate from the interior of the casting, so as to prevent the solidified and chilled surface from being remelted by the radiation of internal heat.

b. *Chill-mould for a railroad wheel.* In this case it must be considered that only the rim is to be hard, while the spokes and hub are to show the constitution of ordinary cast iron so that they can be

worked and are less exposed to the danger of breaking. The mould, Fig. 8, also consists of three parts. The middle part is the chill *S*, *I* is the lower part, *III* the upper part with the cast-gate *E*, and *K* the core for the hub aperture. The lower part is a box of common round form, merely to hold the sand and give support to the centre core and the middle box.

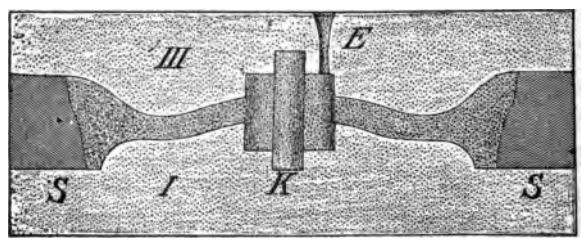

FIG. 8.

The upper box is of similar form, also round. The middle box *S*, is a solid ring, cast of mottled iron and bored out upon a turning lathe, giving its interior the reverse of the exact outer form of the rim of the wheel. This middle box ought to be at least as heavy as the wheel is to be, after casting, and it is preferable if it has two or three times that weight. All the three boxes are joined by lugs and pins as usual, and the latter should fit well without being too tight. The chief difficulty in casting these chilled wheels, is to make the cast of a uniform

strain to prevent the wheels from breaking, and wheels with spokes or arms are very liable to do this.

At present most of these wheels are cast with corrugated discs or plates. In this way the hub may be cast solid, and the wheel is not so liable to be subjected to an unequal strain as when cast with spokes. In such plate-wheels the whole space between the rim and the hub is filled by metal. The rim of a good wheel should be as hard as hardened steel at its periphery, but soft and grey in its central parts. The first requisite is more safely attained by having a heavy chill; but if the chill is too heavy, the inner parts are apt to suffer from the cooling qualities of the chill. Success in this branch of founding depends very much on the quality of the iron of which the wheels are cast. Soon after casting such wheels it is advisable to open the mould, and remove the sand from the central portion, so as to make it cool faster. This precaution saves many castings, not only in this particular case, but in many other instances. Uniformity in cooling is as necessary to success as good moulding.

The following is a brief description of the largest establishment for the manufacture of chilled wheels in the United States, and the manner in which the work is advanced from stage to stage: The foundry,

which is of course the most important portion of the whole works, is provided with two lines of rails running down its whole length, except opposite the furnaces. The rails are laid to a gauge of about 10 feet, and upon them are placed 12 light travelling cranes, with a platform attached to the centre-post, and upon which the man working the crane stands and controls its movements, both in hauling the moulds and ladles, and in moving the crane from place to place upon the line, the crane being geared for travelling. The floor of the foundry is so laid out that there is room on either side of both pairs of rails for a row of moulds, and in the centre of the building is a path about 4 feet wide. Against one side of the building, and in the centre of its length, are five cupolas, three of 4 feet 6 inches internal diameter, and two smaller ones of 18 inches diameter. The former are employed in melting the iron for the wheels, the latter chiefly for experimental purposes. The three cupolas are tapped into converging channels, all running into one large tipping reservoir, from which the small ladles are supplied. The blast to the cupolas is furnished by a vertical blowing engine, with two blowing cylinders, one at the top of the machine and one at the bottom, with the steam-cylinder between the two.

The mixing of the irons for the cupola is the most important and difficult operation in the whole course of manufacture. Besides the steel-scrap nothing but charcoal pig iron is employed, and of this from twelve to twenty different kinds, all of the highest class, are used in varying proportions. But these mixtures have to be altered frequently, owing to irregularities in the nature of the metal, and daily tests are made, with a view of ascertaining what changes, if any, have to be introduced into the next day's work. The proportions of the mixture being decided upon, the cupolas are charged, a ton of coal being first put into the bed of each furnace. The charge is then carefully loaded upon trucks upon a weighing platform. Piles of the various pigs are placed in their proper order around the truck, and there is a drum upon the weighing machine, on which a sheet of paper is placed, and the weight of each different pig, in proper order, is written upon it. For instance, the workman commences with 250 lbs. of coal in his truck; he then places 125 lbs. of old steel rails, 125 lbs. of cinder pig, 350 lbs. of old wheels, and so on through the long list of charcoal pig iron employed, the old material being placed at the bottom of the furnace. The weighing platform is so arranged as to record the accumulating weights

as the drum revolves, bringing before the workman the name and quantity of each successive ingredient which he takes from its respective heap before him. As soon as it is loaded the truck is raised to the top of the cupola by a hydraulic lift. The moulds, when ready, are placed down the building in four rows, one on each side of the two lines of rail upon which the cranes run. The patterns used are almost all in iron, and the chills in the moulds are of cast iron. One workman can, on an average, mould ten wheels per day, but all failures in the casting arising from any carelessness in moulding, are charged to him on a rapidly increasing scale.

Before the metal in the cupola is ready to run, a charcoal fire is lighted in the previously mentioned receiver, in order to warm it, and also that when filled the metal may be covered with charcoal and oxidation checked. In a similar manner the ladles, of which there are a very large number employed, have burning charcoal placed in them, and they are internally coated in the usual way. These ladles are cylindrical pots made of sheet iron and mounted each on a pair of wheels for facility of transport. On the sides of each ladle are two sockets, into one of which the end of a long iron handle is inserted for hauling it along the floor. Also at each end of the axle is a

square hole, into which is placed the end of a handle with forked ends. The ladle being run up to the receiver, the latter is tipped over by the gearing attatched to it, and the ladle is charged; it is then brought along the floor to the crane, which takes hold of it. The two square-ended handles before mentioned are inserted in the holes in the axles, the ladle is raised, and the iron poured into the mould. The chilled portion of the wheel sets almost as soon as it comes in contact with the chills, and in a very short time after the casting has been made, the flasks are removed, the sand is knocked away, and the red-hot wheel is placed on a truck to be taken to the annealing pits. This process is one of the most important of the series. If the wheel be allowed to cool in the open air, severe internal strains are created which will sometimes be sufficient to destroy the casting, and open air cooling was the chief cause of failure in the early periods of this class of wheel making.

The annealing ovens are placed at one end of the foundry, and below the floors, the tops of the ovens being at that level. Besides these ovens of very large diameters for extra-sized wheels, chilled tires, etc., there are 48 pits ranged in 6 rows of 8 each. These rows are divided into pairs, each pair of 16

pits being devoted to the reception of one day's production, the period required for annealing being 3 days. By this arrangement, when the last two rows of ovens are charged, the first two rows can be emptied and refilled, so that the work proceeds without interruption and in regular rotation. Two hydraulic cranes with the booms revolving upon a fixed post, are placed upon the floor and command the whole area occupied by the ovens. The boom of each crane is made double, and upon it runs to and fro a small carriage, from which hangs the chain, carrying at the lower end the hooks by which the wheels are handled. This attachment consists of three arms with flattened ends turned over so as to grip the wheel. The upper ends of these arms are hinged together, and as they tend always to fall inward, they hold the wheel tightly, but by moving a single attachment the arms are thrown outward when it is desired to release the wheel. The motion of the cranes is controlled by one man, fixed stops being provided on the guiding apparatus, so that when the crane is adjusted for filling one oven it remains in that position till it is thrown over to the next.

The ovens or annealing pits are cylinders of sheet iron $\frac{1}{8}$ inch thick, about 66 inches in diameter, and

of sufficient depth to contain easily 18 wheels with cast-iron distance pieces between them. They are lined with brick-work, and being of considerable depth, they descend into a lower floor. The lower parts are enclosed in a large rectangular chamber, one for each set of ovens. Within this chamber, and for a short distance above it, fire brick is used instead of ordinary brick-work as in the upper portions, and within the cylinder a circular foundation of brick-work is set, upon which are placed the wheels on being lowered by the crane. The whole of this weight then is transferred direct to the foundation of the building. At the end of each of the three rectangular chambers already mentioned is a furnace, and each chamber is divided down the whole of its length by a perforated flue; through these perforations the heat from the furnace passes and enters the lower ends of the ovens. These furnaces are required to prevent the too sudden cooling of the castings, but only $\frac{1}{4}$ ton of coal is burned for each full day's production. Flues leading to the chimney carry off the heated gases from the upper parts of the ovens, and so the process of cooling is thus very gradually carried on, until at the end of three days the wheels are ready for removal. The three large annealing pits mentioned above are some-

what differently arranged. To save room they are not carried down so low as the other ovens, but terminate at a height of about 7 feet above the floor, each being supported upon a central column. When they are used, a fire is lighted in the bottom of each pit, the wheels are put in and covered over, and the oven is allowed gradually to cool.

On being removed from the pit the wheels are taken into the cleaning and testing room. Here the sand is removed and the wheels tested by hammering under the sledge as well as by a small hammer, while the tread is cut at intervals by a chisel. The heavy blows to which the wheel is subjected never fail in detecting faults when such exist, and when they are discovered the wheel is removed to be broken up. About 10 per cent. of the whole production is rejected, but occasionally this proportion is very much higher.

In order to keep the quality of the wheels up to the desired standard, a large number of test-pieces are cast every day and submitted to examination. By this means an accurate knowledge of the nature of the wheels, the character of the chill, and other points, is obtained; the data are carefully recorded, and if the tests are satisfactory, the wheels corresponding to the test-piece are delivered into stock.

If not, they are returned to be broken up. The sound wheels are finally taken to the machine-shop, where they are bored, and, if desired, fitted with their axles. The tools, therefore, in this shop are

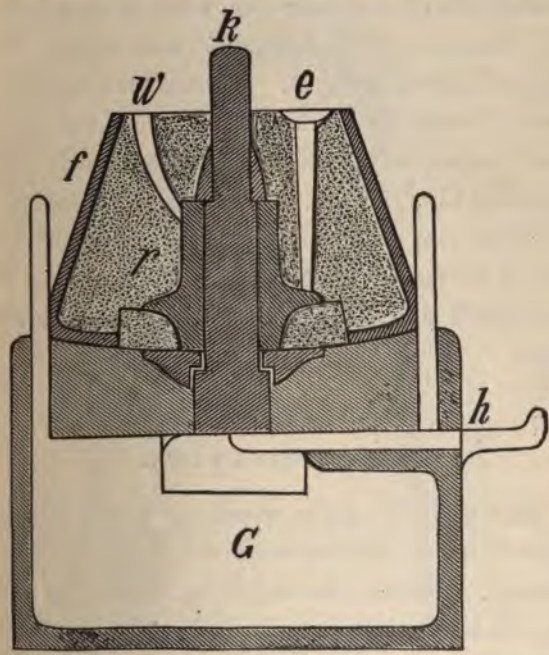

Fig. 9.

few in number, consisting of three boring machines, a press for forcing the wheels on or for drawing them off the axles, and a number of lathes.

The average life of a chilled cast iron wheel of

first quality is asserted to be 50,000 miles for passenger and 100,000 miles for freight traffic.

c. For the preparation of hollow chill-castings, F. Tellander has patented a process which consists in casting around a metallic core, which as soon as the iron begins to solidify is removed from below. The method is shown in Fig. 9. Around the (dark) iron core *k*, is cast the (dark hatched) wheel-box *r*, the inner surface of which is to be hardened. The moulding-box *f* is filled with sand and the cast-gate *e* and the vent *w* are arranged. After the solidification of the casting, the leaver *h* is withdrawn and the core *k* falls into the vessel *G*, which is filled with water.

CASTING WITHOUT CORE.

This mode of casting would, no doubt, be used more if it were not connected with a peculiar disadvantage. Casting without core is executed by pouring the fluid metal (zinc, tin, lead, or alloys of these metals) into a mould, generally of brass, with a comparatively large gate, whereby the gate must, of course, be kept uppermost, just the reverse of the position shown in the illustration (Fig. 10). The mould *b* entirely filled with liquid metal is then mo-

or less quickly inverted, so that it comes in the position shown in the illustration. By not allowing time for complete congelation, the larger portion of the metal poured in will run out, whilst a crust *c* of

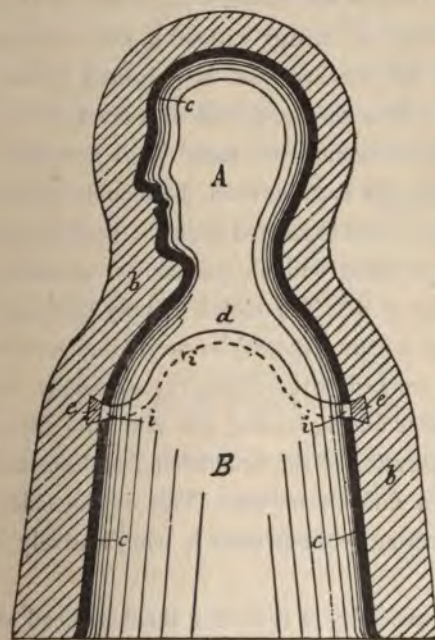

Fig. 10.

more or less thickness remains in the mould and forms a casting useful for many industrial purposes.

To obtain solid castings free from blowholes, the metal must stand under a certain pressure, which is

also required for other castings. For this purpose a "dead-head" (riser or sullage piece) is used, and as the dead-head is also hollow, after inverting the mould, this portion of the casting is called the "funnel." In the illustration a small bust *A* is given as an example of casting without a core; the lower portion of the finished bust is indicated by the curved line *d*; *B* is the dead-head or funnel which simply serves for making the metal in *A* compact. After removing the casting from the mould, the dead-head or funnel *B* is separated from the casting by sawing, filing, or other suitable mechanical treatment along the edge of *d*. The metals chiefly used for casting without a core possess, however, the peculiarity of being worked with difficulty, especially zinc and many zinc alloys, fouling the saws and files, so that the separation of the dead-head from the casting becomes a difficult matter. This is the chief reason why casting without core is comparatively little use.

The necessity of removing the dead-head or funnel by sawing, filing, etc., is, however, entirely done away with by working in the mould *b*, along the edge of *d*, a groove *e*. This groove is filled with a material which is a bad conductor of heat, but will stand a high temperature, asbestos being especially recom-

mended for the purpose. Now, while the fluid metal, when poured in, congeals on the metallic walls of the mould, they being good conductors of heat, congelation does not take place along the line of the asbestos, the metal poured in remaining fluid, or at least much more fluid on this point than on other places of the mould. By now inverting the mould, the strip *i* lying opposite to the groove *e* filled with asbestos runs out together with the metal, filling the mould, and when taking the mould apart the dead-head or funnel *B* will be found separated from the actual casting, or connected with it only by a very thin film, which can be readily severed.

CASTING ON TO OTHER METALS.

It is occasionally desired to unite other metals by means of cast-iron, or to fix ornamental castings on to light work made of wrought-iron or steel.

Such a process cannot be practised with cast-iron upon any of the other useful metals than cast-iron, wrought-iron, or steel, as all the other metals, commonly used, have melting points so much below that of cast-iron that they would not bear coming in contact with liquid cast-iron.

Sometimes non-metallic substances, such as grind-

stones, etc., are held in shape by rings or bands of iron cast round them.

When iron is cast upon or around solid wrought-iron or steel, certain changes are brought about upon these metals. The cast-iron when thus brought into contact with the comparatively cool surface of the solid wrought-iron or steel will of course be "chilled" at and around all points of contact. It will therefore be harder, more brittle, and much less tough in these parts, and this result will occur wherever liquid cast-iron comes in contact with either solid cast-iron, or wrought-iron, or steel.

When wrought-iron is employed it is found to undergo a certain amount of deterioration, both in toughness and cohesion, becoming of less value for structural purposes where those qualities are required. Steel suffers in the same manner, but to a much less extent. A bar of cast-iron cast around a core of wrought iron will be found little, if anything, stronger than a simple bar of cast-iron of the same size. Consequently where the full strength and toughness of these metals are required, "casting on" should be avoided, and especially in any work which will be exposed to sudden shocks, or varying strain.

But a very large number of useful and ornamental articles, requiring little absolute strength, can

most readily produced by the process of casting on, such as hand-rails, window frames, panels, hat and umbrella stands, bedsteads, or ornamental gates.

One well-known application of this process is Moline's invention for the combination of wrought and cast-iron in the manufacture of window frames. The sash-bars are formed of wrought-iron, rolled of any light and convenient section, suited to receive glass; these bars are united by ornamented cast-iron bosses.

An iron pattern is first made, from which a sand mould is obtained, the wrought-iron bars are cut to the required lengths, and placed in the mould, with their ends nearly touching; over these ends the mould of the boss is placed, which must be sufficiently large to cover them, so that when cast on, the bosses shall firmly unite the wrought-iron bars. These windows can be readily made of any usual size and shape, and are easily fixed. They are light in appearance, and combine the strength of wrought-iron with the ornamental character, which can easily be obtained by the addition of cast-iron flowers, scrolls, armorial bearings, or other ornaments.

For ornamenting wrought-iron railings, two ways of applying cast-iron may be mentioned. Either the wrought-iron bars may be placed in the moulds, and

the ornaments cast round their ends, or the ornaments may be cast in green-sand moulds, cored out to fit the wrought-iron bars, on to which they are afterwards fixed by an alloy of zinc and lead. Lead alone is to be avoided, as it sets up a galvanic action, and assists the formation of rust.

In designing cast-iron railings it will be well to adopt outlines in which the metal will not be unfairly strained, by the union of very light and heavy pieces in the same casting. Discard all very fine ornamental work for streets where there is much traffic, as accident or mischief will very shortly spoil the beauty of the work, which cannot be repaired. Ornamental cast iron work of an intricate character is only in place where it can be seen to advantage and is not exposed to violence.

Exposed to the air in large cities, cast-iron railings are much more durable than those of wrought-iron.

If cast-iron chill moulds are used for the ornamental castings, the ornaments will naturally be rather brittle; in most cases this will be found of little consequence, but where it is desired to avoid brittleness, the work can be placed in an annealing oven, when the cast-iron will be made into malleable cast-iron, without prejudicially affecting the wrought-

iron, if any is used in conjunction with the cast-iron, as is frequently the case.

Burning-on is also frequently practised, for the purpose of ornamenting wrought-iron with scrolls, volutes or twisted forms. Loam moulds are made, and when thoroughly dried, are applied to that portion of the wrought-iron which it is wished to burn on to; cast-iron is then poured through the moulds until the wrought-iron is brought to a welding heat; pouring is then ceased, and the cast-iron, when cooled down, is found firmly affixed to the wrought-iron.

For ornamental cast-iron railings which are designed with comparatively heavy pilasters and bars, having the intervals between them filled in with light ornamental work, the two should not be cast at one and the same time, otherwise the light work will be almost certain to break away from the heavy, owing to the unequal contraction in cooling. The ornamental work should be cast first, of fine, soft, fluid iron, and be provided with small-fitting pieces or lugs, at convenient points, for fixing to the heavy bars or uprights. Coat these lugs on the fine work with clay and black-wash, place it in a sand mould, and cast the heavy work round it. By so doing the iron will not be liable to fracture from unequal con-

traction and expansion. Burning-on is sometimes of service in repairing a broken or damaged casting, but the process is neither applicable to fine, delicate work, nor to cases where the size and shape of the original castings must be strictly preserved, as in a cast-iron wheel, which would probably be twisted out of shape by the expansion and subsequent contraction of the metal during the operation of burning-on.

But a piece of machine framing, the necks of rolls, or a standard which has been broken or found defective, may be repaired as follows: First cut away the defective parts down to the sound metal, build a coke-fire round the part of the casting which is to be repaired until it is brought to a bright red heat, then dust over the surface of the cut metal with powdered glass or borax. Then apply a hollow loam mould of the desired part to the casting, properly secured in position, and provided with a hole for the exit of the metal. Pour very hot liquid cast-iron into the mould, and allow it to flow away until the cut surface of the original metal of the casting can be felt with an iron bar to have become soft and pasty by contact with the hot liquid iron. Then stop the exit hole, and allow the metal in the mould to set. If the operation has been properly performed the casting should ring, when struck, with the same sound as a single

good casting, thus showing that the old and new metal are perfectly united.

Where portions of large castings require to be removed for this burning-on process, the easiest mode of doing it is to cut the casting while at a cherry red heat, with a rapidly revolving circular saw, such as is used for cutting off the "crop-ends" of rolled rails.

Cast iron may also be bent to a considerable extent with safety at a cherry-red heat, which quality is occasionally of service in remedying variations from the desired shape, arising from contraction in cooling. The bench or surface on which such bending is to be performed must be constructed of non-conducting material, such as baked fire-clay, otherwise the iron will part with its heat too suddenly, and break rather than bend.

Holes occur occasionally on the surface of a casting, which although not of sufficient importance to make it advisable to reject or break up the casting, are unsightly. Liquid cast-iron may be poured into such holes, the superfluous metal being removed by an iron straight-edge. It is usually preferred, however, to fill up these cavities with an alloy having a similar appearance to the cast-iron, but being much more fusible. One such alloy consists of antimony

69 parts by weight, copper 16, tin 2, melted together, to which add afterwards lead 13 parts by weight. Another alloy for the same purpose consists of antimony 65 parts by weight, copper 16, lead 13, prepared in the same way.

CASTING BRASS NUTS ON SCREWS.

POLISH the screw, make a mould on it, with a gate or runner at the end; when the mould is horizontal, 1 inch in diameter, 5 inches high, scoop out the top 3 inches diameter beveled down to 1 inch; second, make the gate or runner on the top of screw ½ inch diameter, same height as the other. Take a pricker and prick from the top of the mould to the pattern nut about a dozen holes, after which draw diamonds with the wire from these holes to the sides of the mould on the top. Now part the mould, draw the nut and screw, cut the gates, making the one at the end of nut same as the down one, an inch in diameter; take the screw, smoke it over a gas-flame, turning it round, pouring a little oil on it. Continue heating till the oil begins to boil; at this stage take a little dry parting-sand, which is used to part the mould; sprinkle this all around the top of the oil; heat now as before to a dull red heat, and proceed as

before. Remelt the metal, take 3 lbs. of old waste handles, free from iron, add to this 9 lbs. of copper, melt both, and when ready for casting add ½ lb. of zinc or spelter; allow it to remain in the fire 10 minutes; take it out, add ½ lb. of block tin and ¼ lb. of lead; stir the whole well up. The screw is now red and in the mould. Rush the metal quickly in at the gate, 1 inch diameter; be sure the metal is hot, and it will rise at the other gate to the top of the mould. Be careful at this stage. To take the nut off do not heat it; dress it as before; hammer it cold, heat it; now hold the screw upright, pour on oil at the top of the nut, allow it to cool, catch nut in vice, apply a lever to the square at end of screw, and turn it round.

A NEW PROCESS OF CASTING IRON AND OTHER METALS UPON LACE, EMBROIDERIES, FERN LEAVES AND OTHER COMBUSTIBLE MATERIALS.

Mr. A. E. Outerbridge, Jr., has succeeded in moulding fine lace in cast-iron, the impression showing the most delicate lines of the pattern. The lace to be moulded must first be carbonized. In place of lace, other fine tissues, embroidered ornamentations upon stuffs, leaves, grasses, etc., may also be

moulded, previous carbonization being, however, always required. The process, as described by Mr. Outerbridge at a stated meeting of the Franklin Institute, Philadelphia, is as follows: The objects are placed in a cast-iron box, the bottom of which is covered with a layer of powdered charcoal or other form of carbon, then another layer of carbon dust is sprinkled over them, and the box is covered with a close-fitting lid. The box is next heated gradually in an oven, to drive off moisture, and the temperature slowly raised until the escape of blue smoke from under the lid ceases. The heat is then increased until the box becomes white-hot; it is kept in this glowing condition for at least two hours. It is then removed from the oven, allowed to cool, and the contents are tested in a gas flame. If they have been thoroughly carbonized, they will not glow when removed from the flame, and the fibres may even be heated white hot before consuming.

Of course the method employed to carbonize the materials is susceptible of variation, but the scientific principles involved are unchangeable, viz.:

1. Partial exclusion of air and substitution therefor of a carbon atmosphere.

2. Slow heating to drive off moisture and volatile elements.

3. Intense and prolonged heating of the partly charred objects to eliminate remaining foreign elements, and to change the carbon from the combustible form of ordinary charcoal to a highly refractory condition.

In the first experiments the mould was made in "green sand" in the ordinary manner, and the fabric laid smoothly upon one face, being cut slightly larger than the mould, in order that it might project over the edge, so that when the moulding flask was closed the fabric was held in its proper position. As the melted metal flowed into the mould, it forced the fabric firmly against the sand wall, and when the casting was removed the carbonized fabric was stripped off from its face without injury. In this way several castings have been made from one carbonized material.

The castings are as sharp as electrotypes, whether made of soft fluid iron or hard quick-setting metal. This peculiarity is owing to the affinity between melted iron or steel; the melted metal tends to absorb the carbon as it flows over it, thus causing the fabric to hug the metal closely. It is somewhat analogous to the effect of pouring mercury over zinc. As is well known, when mercury is poured upon a board, it runs in a globular form—it does not "wet

the board, so to speak; but when poured upon a plate of clean zinc, it flows like water and wets every portion of the zinc; or, as we say, it amalgamates with the zinc. So when melted iron is poured into an ordinary sand mould, which has been faced with this refractorily-carbonized fabric, it wets every portion of it, tending to absorb the carbon, and doubtless would do so if it remained fluid long enough, but as the metal cools almost immediately, there is no appreciable destruction of the fibres.

CORES IN HEAVY CASTINGS.

WHEN cores run through heavy bodies of iron, the hot liquid raises the fusible element of the sand to such a temperature that the grains fuse together, so that when the casting-cleaner tries to get the core out, he finds it almost as hard as the iron. A good thing to prevent this fusing of the sand is to mix some sea-coal or blacking in it, and to give the surface of the core a good body of black lead or plumbago blacking. This outside coat of blacking will prevent the liquid iron from eating into the surface of the core-sand, and the sea-coal or blacking mixed in the sand burns away and passes off in the form of gas, leaving a porous

body between the grains of sand, which assists in preventing its fusion.

In putting rods in such cores as are subjected to a high temperature, it is a good plan to coat them with two or three coats of flour paste and dry them in an oven as it is put on; for by doing this the dried paste burns off from the rod and leaves it free to come out of the casting.

CORE FOR DIFFICULT CASTINGS.

The following are instructions for a composition for cores that may be required for difficult jobs, where it would be very expensive to make a core-box for them: Make a pattern (of any material that will stand moulding) like the core required. Take a mould from the same in the sand, in the ordinary way, place strengthening wires from point to point, centrally, gate and close your flask. Then make a composition of 2 parts brickdust and 1 of plaster of Paris, mix with water, and cast. Take it out when set, dry it and place it in the mould warm, so that there may be no cold air in it.

BRASS MIRRORS.*

An Etruscan mirror, placed in the hands of "Gerharht of Berlin," was found to consist, in 100 parts, of 67.12 copper, 24.93 tin, 8.13 lead; approximating closely to an alloy of 8 parts copper, 3 of tin, and 1 of lead. The oxide of tin obtained in the course of analysis was carefully examined before the blow-pipe for antimony, but he saw no trace of that metal.

A similar mirror has been analysed by "Klaproth." He found 62 per cent. copper, 32 tin, and 6 per cent. lead.

Copper.—Copper is thick and pasty, and without some alloy will not run into the cavities and sinuosities of the mould.

Metals.—A quarter of a grain of lead will render an ounce of gold perfectly brittle, although neither gold or lead are brittle metals.

* See Job, xxxvii. 18; Exodus, xxxviii. 8.

Surface of Metals.—The surface of metals should be carefully defended, while in the fluid state, from the action of the atmosphere, by a stratum of wax, pitch, or resin, if the fusing point be low; or by a layer of salt, powdered glass, borax, charcoal, &c., if it is high.

Blanched Copper.—8 ounces of copper, and ½ an ounce of neutral arsenical salt, fused together under a flux of calcined borax and pounded glass, to which charcoal powder is added, makes blanched copper.

British Weapons and Tools in Bronze, anciently called Corinthian and Syracuse Brass.—The metal of which the British weapons and tools were made, has been chemically analysed in modern times, and the proportions appear to be—

In a spear head,	1	part of tin to	6	parts of copper.
In an axe head,	1	do.	10	do.
In a knife,	1	do.	7½	do.

ON BRASS.

In Germany brass appears to have been m
for centuries before the manufacture was introdu
into England. This is stated to have been done
a German, who worked at Esher, in Surrey, in
year 1649. The analysis of a few pieces of bro
of undoubted antiquity, namely, a helmet with
inscription (found at Delphi, and now in the Brit
Museum), some nails from the treasury of Atre
at Mycenæ, an ancient Corinthian coin, and a p
tion of a breast-plate, or cuirass, of exquisite wo
manship (also in the British Museum), affords ab
87 to 88 parts copper to about 12 to 13 tin,
cent.

The experiments of Klaproth and others gi
nearly the same results as to ingredients; the qua
tities sometimes slightly differ. Lead is contain
in some specimens, as has been shown. Zinc, an
the nature of it, as heretofore observed, was no
known to the ancients.

In an antique sword, found many years ago, in

old and silver, amalgamation takes place readily, y mere contact. When, on the other hand, the hesion of a metal is strong or its affinity for mer- ry is weak, heat or intermediate action, or both, e requisite to effect amalgamation.

If forty-four parts of mercury be mixed with one rt of potassium, combination occurs with the evo- tion of much heat; and when the resulting amal- m is cold, it is hard and has the appearance of lver. When the quantity of mercury exceeds one ndred parts to one of potassium, the compound is quid, and an amalgamation containing only 1.5 er cent. of potassium is susceptible of crystalliza ion. The density of an amalgam exceeds that of he mean of the metals; this and the tendency of ne or both metals to oxidize, are additional indica ions of chemical combination.

There are some metals, it has been observed, re- quiring heat to amalgamate them. Antimony offers an example of this: to effect combination it must be melted, and while liquid mixed with hot mercury. Mere heat, however, causes scarcely any action be- tween iron and mercury; they may be amalgamated by mixing the filings of the metal with powdered alum, and rubbing them together in a mortar with a little water. After trituration, the alum may be

washed out. By the intervention of tin or zinc, iron may be combined with mercury, and a double amalgam is formed. Platina also unites with mercury, by the intervention of the amalgam of potassium, but not by direct action. The double amalgam of iron and zinc does not rapidly undergo any change, and is not attracted by the magnet. All amalgams are decomposed by a red heat; the mercury being distilled, and the more fixed metal remaining. The process of amalgamation and decomposition is employed to separate gold and silver from their ores. The mercury obtained by decomposing the amalgams is distilled and repeatedly used for the same purpose, with comparatively little loss.

The amalgams of gold and silver are used or employed in the process of gilding and plating. We have also shown the amalgam of tin is largely used in what is called silvering mirrors, and that various amalgams of tin and zinc are employed for exciting electricity in the machine.

BISMUTH.

At a high temperature this metal is volatilized; may be distilled in close vessels, and solidifies in foliated crystals. If it be merely melted in a crucible, and cautiously cooled, it crystallizes in well-defined cubes. Bismuth, as met with in commerce, is not pure, for it generally contains iron and arsenic. In order to purify it, it is to be dissolved in nitric acid; the solution is to be decomposed by water, and the precipitate, after being boiled in a solution of soda, is to be mixed with black flux, and moderately heated in a crucible.

Bismuth combines with copper to form a pale-red brittle alloy. It forms a brittle compound with silver; and it has been proposed as a substitute for lead, in refining silver. It is said to form a more fluid oxide, which penetrates the cupel more readily than that of lead; and may also be used in smaller quantity.

With mercury it forms a very fluid alloy, and makes the following metals brittle by combination: tungsten, palladium, rhodium, gold, and platina.

It is principally employed in making fusible alloys, and as an ingredient in solders. It is often called in the arts "tin glass."

ON FRICTION.

FRICTION is independent of the velocity; at least when the velocity is neither very great nor very small. With hard substances, such as wood, metal, and stone, the amount of friction is simply as the pressure, without regard to surface, time, or velocity. Friction is greatest with *soft*, and least with *hard* substances. The diminution of friction by *unguents* depends on the nature of the *unguents*, without reference to the substances moving over them.

The following table shows the comparative amount of friction of different metals, under an average pressure of 54.25 pounds to 69.55 pounds.

Names of Metals, Tried.	Average Weight.	Proportions.	Weight per Square Inch.
	lbs.		*lbs.* *oz.*
Brass on Wrought Iron . .	69.55	7.312	11 12.4
Steel upon Steel	69.55	6.860	11 12.5
Brass upon Cast Iron . . .	54.25	6.745	8 0.5
Brass upon Steel	69.55	6.592	11 12.5
Hard Brass upon Cast Iron	54.25	6.581	6 15.9
Wro't Iron upon Wro't Iron	69.55	6.561	11 12.5
Cast Iron upon Cast Iron .	54.25	6.475	8 0.5
Do. do. Steel . . .	69.55	6.393	11 12.5
Do. do. Wro't Iron	69.55	6.023	11 12.5
Brass upon Brass	69.55	5.764	11 12.5
Tin upon Tin	69.55	3.305	11 12.5

From hence it would appear that *hard metals* have less friction than *soft ones;* and that the friction of *hard* against *hard* may be generally estimated at about one-sixth of the *pressure.*

Relative to unguents, Sir John Rennie's experiments show that for gun metal or cast iron, with oil intervening, and a weight of 1120 pounds, the friction amounted to $\frac{1}{8}$.63 of the pressure; but on diminishing the insistent weights the friction was diminished to $\frac{1}{17}$.33.

BELLS.

THE large bells now used in churches, are said to have been invented by Paulinus, Bishop of Nola, in Campania, about the year 400: whence the "Nola" and "Campania" of the lower Latinity. They were probably introduced into England very soon after their invention. They are first mentioned by Bede, about the close of the seventh century. Ingulphus records that Turketul, Abbot of Croyland, who died about the year 890, gave a bell of a very large size to that abbey, which he named Guthlac. His successor, Egelric, cast a ring of six others, to which he gave the names of Bartholomew, Bettelin, Turketul, Tatwine, Pega, and Bega. Baronius informs us that Pope John XIII., A. D. 968, consecrated a very large new cast bell, in the Lateran Church, and gave it the name of John. The ritual for the baptizing of bells may be found in the Roman Pontificale.

The city of Nankin, in China, was anciently famous for the largeness of its bells, as we learn from Father le Compte; but they were afterwards far exceeded in size by those of the churches of Moscow

A bell in the tower of St. Ivan's Church, in Moscow, weighed 127,836 English pounds, or 57 tons 1 cwt. 1 qr. 16 pounds. A bell given by the Czar Boris Godunof to the Cathedral of Moscow, weighed 288,000 pounds, or 128 tons 11 cwt. 1 qr. 20 lbs. And another, given by the Empress Anne, probably the largest in the known world, weighed 432,000 pounds, or 192 tons 17 cwt. 0 qrs. 26 pounds. According to Coxe (Travels in Russia, vol. 1, page 322), the height of this last bell was 19 feet, the circumference at the bottom 63 feet 11 inches, and its greatest thickness 23 inches. The great bell of St. Paul's, London, weighs 12,000 pounds, and is 9 feet in diameter.

The largest bell in England, is "Great Tom," of Christ Church, Oxford, which is 17,000 pounds weight.

ON FLUXES.

BLACK FLUX is made by mixing one part of powdered nitre with two parts of powdered *aryol*, which is the commercial name for impure cream of tartar, or bitartrate of potash.

This mixture is to be gradually thrown into a red-hot earthen crucible, so as to deflagrate it, taking care not to make the heat so high as to fuse the mixture.

In this case, the nitric acid of the nitre is decomposed, its oxygen acts upon the carbon of the tartaric acid, carbonic acid is formed, and this uniting with the potash, both of the nitre and bitartrate, is converted into carbonate of potash. The whole of the carbon of the tartaric acid is not, however, so acted upon; and the excess remains mixed with the carbonate of potash, in the state of finely divided charcoal.

This flux should be immediately reduced to powder, and kept in a well stopped bottle; otherwise it will become damp by the absorption of moisture, to which the carbonate of potash is subject. This flux is doubly useful; the carbonate of potash combines with the earthy parts of the *ore*, such as *silica* and *alumina*, while the charcoal unites with the oxygen of the metallic oxides, and, carbonic acid being formed and expelled, the metal is reduced and melts. This flux is especially useful in the process of detecting arsenious acid, and reducing it to the metallic state.

Argol, already described, is an impure bitartrate

of potash, powdered and mixed with the pulverized substance to be reduced, and is sometimes advantageously used as a flux. Owing to the intimate mixture of the charcoal and potash in this flux, a good deal of potassium is evolved; and upon the reducing property of this metal, the reduction of the oxides of other metals frequently depends to a considerable extent.

Charcoal alone is, in the case of pure oxides, sometimes employed as a flux: thus, a crucible lined with charcoal is useful for the reduction of oxide of iron; or the oxide may be mixed with charcoal.

Sal-enixum, or the refuse from aquafortis, is an excellent flux for copper, &c.

FUSING AND MELTING POINTS, ASCERTAINED BY MEANS OF PROFESSOR DANIEL'S REGISTERED PYROMETER.

Mercury, ...	—39°	Fahrenheit.
Tin, ...	442°	Crichton.
Bismuth, ...	497°	do.
Lead, ...	612°	do.
Zinc, ...	773°	Daniel.

Antimony	809°	Daniel.
Silver, ...	1873°	do.
Copper, ...	1996°	do.
Gold, ...	2016°	do.
Cast iron, ...	2787°	do.

Bismuth is mentioned by Agricola, about the year 1529, A. D. It is of a reddish-white colour; its lustre is considerable, and its structure lamellated. It is so brittle as to be easily reducible to powder. When cold, its density is 9.83. It melts at 462°. according to Crighton, jr.; Irving, 476°; Daniel, 497°. Thus even doctors disagree. Probably, however, the specimens experimented upon might have slightly varied as to quality—the reader is furnished with all the facts.

FLUIDITY.

ACCORDING to Dr. Irving, the undermentioned bodies contain the annexed quantities of heat when rendered fluid:—

Lead, ...	162°	Fahrenheit.
Zinc, ...	493°	do.
Tin, ...	500°	do.
Bismuth, ...	550°	do.

ANTI-FRICTION METALS.

MANY use 9 and 10 parts tin to 1 part copper.

A superior composition to either of the above is, 1 part copper, 1 part regulus of antimony, to 10 parts of tin. Melt the copper first, then add the antimony, with a small portion of tin; cover up the whole with charcoal for a short time prior to casting; add the remainder of the tin. These compositions are solely used for lining brass bearings.

The following is an excellent anti-friction metal, not used for linings, but used in castings instead of brass: namely, 85 parts zinc, 10 parts tin, to which is added 5 parts of antimony.

TABLE FOR CONVERTING DECIMAL PROPORTIONS INTO DIVISIONS OF THE POUND AVOIRDUPOIS.

Decimal.	oz.	dr.	Decimal.	oz.	dr.	Decimal.	oz.	dr.	Decimal.	oz.	dr.
.39		1	12.89	2	1	25.39	4	1	37.85	6	1
.78		2	13.28	2	2	25.78	4	2	38.28	6	2
1.17		3	13.67	2	3	26.17	4	3	38.67	6	3
1.56		4	14.06	2	4	26.56	4	4	39.06	6	4
1.95		5	14.45	2	5	26.95	4	5	39.45	6	5
2.34		6	14.84	2	6	27.34	4	6	39.84	6	6
2.73		7	15.23	2	7	27.73	4	7	40.23	6	7
3.13		8	15.62	2	8	28.13	4	8	40.62	6	8
3.52		9	16.01	2	9	28.52	4	9	41.02	6	9
3.91		10	16.41	2	10	28.91	4	10	41.41	6	10
4.30		11	16.80	2	11	29.30	4	11	41.79	6	11
4.69		12	17.19	2	12	29.69	4	12	42.19	6	12
5.08		13	17.58	2	13	30.08	4	13	42.54	6	13
5.47		14	17.97	2	14	30.47	4	14	42.97	6	14
5.86		15	18.36	2	15	30.86	4	15	43.36	6	15
6.25	1	0	18.75	3	0	31.25	5	0	43.75	7	0
6.64	1	1	19.14	3	1	31.64	5	1	44.14	7	1
7.03	1	2	19.53	3	2	32.03	5	2	44.53	7	2
7.42	1	3	19.92	3	3	32.42	5	3	44.92	7	3
7.81	1	4	20.31	3	4	32.81	5	4	45.31	7	4
8.20	1	5	20.70	3	5	33.20	5	5	45.70	7	5
8.59	1	6	21.09	3	6	33.59	5	6	46.09	7	6
8.98	1	7	21.48	3	7	33.98	5	7	46.48	7	7
9.38	1	8	21.88	3	8	34.37	5	8	46.87	7	8
9.77	1	9	22.27	3	9	34.69	5	9	47.27	7	9
10.16	1	10	22.66	3	10	35.16	5	10	47.66	7	10
10.55	1	11	23.05	3	11	35.55	5	11	48.05	7	11
10.94	1	12	23.44	3	12	35.94	5	12	48.44	7	12
11.33	1	13	23.83	3	13	36.33	5	13	48.83	7	13
11.72	1	14	24.22	3	14	36.71	5	14	49.22	7	14
12.10	1	15	24.61	3	15	37.11	5	15	49.61	7	15
12.50	2	0	25.00	4	0	37.50	6	0	50.00	8	0

Application of the Table.

The Chinese Packfong, similar to our German silver, according to Dr. Fyfe's analysis, page 108, is said to consist of—

40.4 parts of	Copper	equivalent to	6 oz.	7 drams, full.
25.4 —	Zinc		4 —	1 — full.
31.6 —	Nickel		5 —	1 — nearly
2.6 —	Iron			7 — nearly
100.0 Parts			16 oz.	0 — Avd.

KELLER'S STATUE COMPOSITION.

THE brothers Keller, who were very celebrated statue founders, used an alloy, 10,000 parts of which contained 9140 parts of copper, 714 parts tin, 118 parts zinc, and 28 parts lead. This is the composition of the statue of Louis XIV., which was cast at a single jet, by Balthazar Keller, in 1669. It is twenty-one feet high, and weighs 53,263 French pounds. These statues are usually miscalled bronze.

The best brass consists of four parts of copper to one part of zinc.

Bronze was well known to the Romans under the name of "*orichalcum*," who took advantage of its resemblance to gold, in robbing the temples and other public places of that precious metal. Thus Julius Cæsar robbed the Capitol of 3000 pounds weight of gold; and Vitellius despoiled the temples of their gifts and ornaments, and replaced them with this inferior metal.

THE CHINESE PACKFONG,*

ACCORDING to Dr. Fyfe's analysis, is said to consist of

40.4 parts of	copper	equivalent to	6 oz.	7 dr. full.
25.4 "	zinc		4 oz.	1 dr. full.
31.6 "	nickel		5 oz.	1 dr. nearly
2.6 "	iron			7 dr. nearly.
100.0 parts.			16 oz.	0 dr.

COPPER.

COPPER, when mixed with as much zinc as possible, that is 89 pounds copper to 100 pounds zinc. becomes white. The best "Goslar zinc" is from the Hartz, Germany.

* Similar to our German silver.

SILVER STEEL.

1 part silver, 500 parts steel, according to Faraday and Stodan. This alloy would be superior to the best steel. Steel also combines with otner metals, such as nickel, platinum, manganese, &c.

COPPER AND ANTIMONY.

75 parts copper, and 25 parts antimony. This alloy is brittle, lamellated, of a violet colour, susceptible of a fine polish, and is more fusible than copper.

ANTIMONY AND TIN, COPPER AND BISMUTH.

100 parts of tin, 8 parts of antimony, 4 parts of copper, and 1 part of bismuth, constitute the compound commonly called *pewter*.

BISMUTH AND LEAD.

1 part of bismuth, and 1 part of lead, a very tenacious alloy, melting at 165° Centigrade, equivalent to 370° Fahrenheit.

2 parts of lead to 1 part of bismuth, gives an alloy which dilates powerfully at the time of cooling. (This property makes it extremely suitable to all castings in which the greatest sharpness and finish are desirable.—H. MEIGS.)

FULL MEASURE OF CAPACITY OF TIN AND LEAD

82 parts tin, and 18 parts lead.

BRILLIANTS OF FAHLUN,

THUS called, are made from 29 parts of tin, and 19 parts of lead A very fusible and brilliant alloy.

QUEEN'S METAL,

IMITATING silver, has great metallic lustre: 9 parts tin, 1 part lead, 1 part antimony, and 1 part bismuth.

TIN AND ZINC.

1 part tin, and 1 part zinc, is almost as tenacious as brass, and melts at 460° to 500° Centigrade, 900° Fahrenheit.

TIN AND IRON.

THESE two metals may be alloyed in all proportions. 35 parts of tin to 65 parts of iron, form an alloy of a clear crystalline gray, and so brittle that it may be reduced to an impalpable powder.

TO SILVER COPPER.

PRECIPITATE silver from its nitric solution by the immersion of polished plates of copper. Take of this silver 20 grains, supertartrate of potass, 2 drachms, common salt, 2 drachms, and of alum, half a drachm. Mix the whole well together.

Then take the article to be silvered, clean it well, and rub some of the mixture, previously a little moistened, upon its surface. The silver surface may be polished with a piece of soft leather.

The dial-plates of clocks, scales of barometers, &c., are plated thus.

MOSAIC GOLD (*or molu*),

MAY be thus made: take copper and zinc, equal parts; mix them together at the lowest possible temperature at which copper will fuse, and stir until a perfect mixture of the metals is effected. Then add gradually small portions of zinc at a time, until the alloy acquires a proper colour, which is

perfectly white while in the melted state. It should then at once be cast into figured moulds. This alloy should contain from 52 to 55 per cent. of zinc.

TO BRONZE BRASS, ETC.

To 6 pounds of muriatic acid, add 2 pounds of oxide of iron, and 1 pound of yellow arsenic. Mix all well together, and let it stand for two days, frequently shaking it in the mean time, when it is fit for use.

Whatever may be the article which requires bronzing, let it be perfectly cleaned, and free from grease; immerse it in the above solution, and let it stand for three hours, or rather till it will turn entirely black. Then wash the spirits off, and dry it in sawdust, which has been found the best.

After the article is perfectly dry, apply to it some wet black, the same as used for stones, and then polish it with some dry black-lead and a brush, and it is ready for lacquering.

LACQUERS.

LACQUERS are used upon polished metals and wood, to impart the appearance of gold. As they are wanted of different depths and shades of colours, it is best to keep a concentrated solution of each colouring ingredient ready, so that it may at any time be added to produce any desired tint.

1. *Deep Gold-coloured Lacquer.*—Seed lac, three ounces; turmeric, one ounce; dragon's blood, a quarter of an ounce; alcohol, one pint. Digest for a week, frequently shaking. Decant and filter.

2. *Gold-coloured Lacquer.*—Ground turmeric, one pound; gamboge, an ounce and a half; gum-sandarach, three pounds and a half; shell lac, three-quarters of a pound (all in powder); rectified spirits of wine, two gallons. Dissolve, strain, and add one pint of turpentine varnish.

3. *Red-coloured Lacquer.*—Spanish anatto, three pounds; dragon's blood, one pound; gum-sandarach, three pounds and a quarter; rectified spirits, two

gallons; turpentine varnish, one quart. Dissolve and mix as the last.

4. *Pale Brass-coloured Lacquer.*—Gamboge, cut small, one ounce; cape aloes, ditto, three ounces; pale shell lac, one pound; rectified spirits, two gallons. Dissolve and mix as No. 2.

5. Seed lac, dragon's blood, anatto, and gamboge, of each a quarter of a pound; saffron, one ounce; rectified spirits of wine, ten pints. Dissolve and mix as No. 2.

The following receipts make most excellent lacquers.

1. *Gold Lacquer.*—Put into a clean four-gallon tin 1 pound of ground turmeric, 1½ ounces of powdered gamboge, 3½ ounces of powdered gum-sandarach, ¾ of a pound of shell lac, and 2 gallons of spirits of wine. After being agitated, dissolved, and strained, add one pint of turpentine varnish, well mixed.

2. *Red Lacquer.*—2 gallons of spirits of wine, 1 pound of dragon's blood, 3 pounds of Spanish

anatto, 3½ pounds of gum-sandarach, 2 pints of turpentine. Made as No. 1 lacquer.

3. *Pale Brass Lacquer.*—2 gallons of spirits of wine, 3 ounces of cape aloes cut small, 1 pound of fine pale shell lac, 1 ounce of gamboge cut small, no turpentine varnish. Made exactly as before.

But observe, that those who make lacquers, frequently want some paler, and some darker, and sometimes inclining more to the particular tint of certain of the component ingredients. Therefore, if a four-ounce phial of a strong solution of each ingredient be prepared, a lacquer of any tint can be procured at any time.

4. *Pale Tin Lacquer.*—Strongest alcohol, 4 ounces; powdered turmeric, 2 drachms; hay saffron, 1 scruple; dragon's blood in powder, 2 scruples; red saunders, ½ scruple. Infuse this mixture in the cold for 48 hours, pour off the clear, and strain the rest; then add powdered shell lac, ½ ounce; sandarach, 1 drachm; mastic, 1 drachm; Canada balsam, 1 drachm. Dissolve this in the cold by frequent agitation, laying the bottle on its side, to present a greater surface to the alcohol. When dissolved, add 40 drops of spirits of turpentine.

5. *Another Deep Gold Lacquer.*—Strongest alcohol, 4 ounces; Spanish anatto, 8 grains; powdered turmeric, 2 drachms; red saunders, 12 grains. Infuse and add shell lac, &c., as to the pale tin lacquer; and when dissolved add 30 drops of spirits of turpentine.

N. B. Lacquer should always stand till it is quite fine, before it is used.

GREEN BRONZE LIQUID.

TAKE one quart of strong vinegar, half an ounce of mineral green, half an ounce of raw umber, half an ounce of sal-ammoniac, half an ounce of gum arabic, two ounces of French berries, half an ounce of copperas, and about three ounces of green oats, if these can be procured, although, if they cannot, the preparation will succeed perfectly well without them. Dissolve the whole in a strong earthen vessel, adding the berries and the oats, over a gentle fire; bring the compound to boil, then allow it to cool, and run it through a flannel bag, when the bronze will be ready for use.

TO SILVER IVORY.

IMMERSE a slip of ivory in a weak solution of nitrate of silver, and let it remain until the solution has imparted to it a deep yellow colour. Then take it out, and immerse it in a tumbler of clear water, and expose it in the water to the rays of the sun. After it has been exposed thus for about three hours, the ivory acquires a black colour, which on being burnished soon becomes a brilliant silver one.

ZINCING.

COPPER and brass vessels may be covered with a firmly adherent layer of pure zinc, by boiling them in contact with a solution of chloride of zinc, pure zinc turnings being at the same time present in considerable excess. The same object may be attained by means of zinc, and a solution of sal-ammoniac or caustic potassa.

TABLE I.—METAL PLATES.

THIS table shows the weight of a square foot of different metal plates, of thicknesses of one sixteenth of an inch to one inch, advancing by a sixteenth :—

Sixteenths.	Wrought Iron.	Cast Iron.	Cast Copper.	Cast Brass.	Cast Lead.	Cast Zinc	Cast Tin.	Cast Silver.
	lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1	2.5	2.3	2.9	2.7	3.7	2.3	2.4	3.4
2	5.1	4.7	5.7	5.5	7.4	4.7	4.7	6.8
3	7.6	7.0	8.6	8.2	11.1	7.0	7.1	10.2
4	10.1	9.4	11.4	11.0	14.8	9.4	9.5	13.6
5	12.7	11.7	14.3	13.7	18.5	11.7	11.9	17.0
6	15.2	14.0	17.2	16.4	22.2	14.0	14.2	20.5
7	17.9	16.4	20.0	19.2	25.9	16.4	16.6	23.9
8	20.3	18.8	22.9	21.9	29.5	18.7	19.0	27.3
9	22.8	21.1	25.7	24.6	33.2	21.1	21.4	30.7
10	25.4	23.5	28.6	27.4	36.9	23.4	23.7	34.1
11	27.9	25.8	31.4	30.1	40.6	25.7	26.1	37.5
12	30.4	28.1	34.3	32.9	44.3	28.1	28.5	40.9
13	32.9	30.5	37.2	35.6	48.0	30.4	30.9	44.3
14	35.5	32.9	40.0	38.3	51.7	32.8	33.2	47.7
15	38.0	35.2	42.9	41.2	55.4	35.1	35.6	51.1
16	40.6	37.6	45.8	43.9	59.1	37.5	38.0	54.6

TABLE II.—CAST METAL BALLS.

Diam.—*Ins.*	Iron.—*lbs.*	Copper.—*lbs.*	Brass.—*lbs.*	Lead.—*lbs.*
1	$\frac{3}{22}$	$\frac{1}{5}$	$\frac{3}{19}$	$\frac{3}{14}$
2	1.1	1.3	1.3	1.7
3	3.7	4.5	4.3	5.8
4	8.7	10.7	10.2	13.8
5	17.0	20.8	19.9	26.9
6	29.5	35.9	34.3	46.4
7	46.8	57.1	54.5	73.7
8	69.8	85.2	81.4	110.1
9	99.4	121.3	115.9	156.7
10	136.4	166.4	159.0	215.0

TABLE III.—CAST IRON PIPES.

THIS table shows the weight of cast iron pipes 1 foot long, of bores from 1 inch to 12 inches diameter, advancing by ¼ of an inch; and of thicknesses from ¼ inch to 1¼ inch, advancing by ⅛ of an inch.

Bore.	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼
In.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1	3.1	5.1	7.4	10.0	12.9	16.1	19.6	23.5	27.6
1¼	3.7	6.0	8.6	11.5	14.7	18.3	22.1	26.2	30.7
1½	4.3	6.9	9.8	13.0	16.6	20.4	24.5	29.0	33.7
1¾	4.9	7.8	11.1	14.6	18.4	22.6	27.0	31.8	36.8
2	5.5	8.8	12.3	16.1	20.3	24.7	29.5	34.5	39.9
2¼	6.1	9.7	13.5	17.6	22.1	26.8	31.9	37.3	43.0
2½	6.7	10.6	14.7	19.2	23.9	28.9	34.4	40.0	46.0
2¾	7.4	11.5	16.0	20.7	25.7	31.1	36.8	42.8	49.1
3	8.0	12.4	17.2	22.2	27.6	33.3	39.3	45.6	52.2
3¼	8.6	13.3	18.4	23.8	29.5	35.4	41.7	48.3	55.2
3½	9.2	14.2	19.6	25.3	31.3	37.6	44.2	51.1	58.3
3¾	9.8	15.2	20.9	26.9	33.1	39.7	46.6	53.8	61.4
4	10.4	16.1	22.1	28.4	35.0	41.9	49.1	56.6	64.4
4¼	11.1	17.1	23.4	30.0	36.9	44.1	51.6	59.4	67.6
4½	11.7	18.0	24.5	31.4	38.7	46.2	54.0	62.1	70.6
4¾	12.3	18.9	25.8	33.0	40.5	48.3	56.5	64.9	73.6
5	12.9	19.8	27.0	34.5	42.3	50.5	58.9	67.6	76.7
5¼	13.5	20.7	28.2	36.1	44.2	52.6	61.4	70.4	79.8
5½	14.1	21.6	29.5	37.6	46.0	54.8	63.8	73.2	82.8
5¾	14.7	22.6	30.7	39.1	47.9	56.9	66.3	76.0	85.9
6	15.3	23.5	31.9	40.7	49.7	59.1	68.7	78.7	88.8
6¼	16.0	24.4	33.1	42.2	51.5	61.2	71.2	81.2	92.0
6½	16.6	25.3	34.4	43.7	53.4	63.4	73.4	84.2	95.1
6¾	17.2	26.2	35.6	45.3	55.2	65.3	76.1	87.0	98.2
7	17.8	27.2	36.8	46.8	56.8	67.7	78.5	89.7	101.2
7¼	18.4	28.1	38.1	48.1	58.9	69.8	81.0	92.5	104.3
7½	19.0	29.0	39.1	49.9	60.7	72.0	83.5	95.3	107.4
7¾	19.6	29.7	40.5	51.4	62.6	74.1	85.9	98.0	110.5
8	20.0	30.8	41.7	52.9	64.4	76.2	88.4	100.8	113.5
8¼	20.9	31.7	43.0	54.5	66.3	78.4	90.8	103.5	116.6
8½	21.7	32.9	44.4	56.2	68.3	80.8	93.5	106.5	119.9
8¾	22.1	33.6	45.4	57.5	70.0	82.7	95.7	109.1	122.7
9	22.7	34.5	46.6	59.1	71.8	84.8	98.2	111.8	125.8
9¼	23.3	35.4	47.9	60.6	73.6	87.0	100.6	114.6	128.9
9½	23.9	36.4	49.1	62.1	75.5	89.1	103.1	117.4	131.9
9¾	24.6	37.3	50.3	63.7	77.3	91.3	105.5	120.1	135.0
10	25.2	38.2	51.5	65.2	79.2	93.4	108.0	122.8	138.1
10¼	25.8	39.1	52.8	66.7	81.0	95.6	110.4	125.6	141.1
10½	26.4	40.0	54.0	68.3	82.8	97.7	112.9	128.4	144.2
10¾	27.0	41.0	55.2	69.8	84.7	99.9	115.4	131.2	147.3
11	27.6	41.9	56.5	71.3	86.5	102.0	117.8	133.9	150.3
11¼	28.2	42.8	57.7	72.9	88.4	104.2	120.3	136.7	153.4
11½	28.8	43.7	58.9	74.4	90.2	106.3	122.7	139.4	156.4
11¾	29.5	44.6	60.1	75.9	92.0	108.5	125.2	142.2	159.5
12	30 1	45.6	61.4	77.5	93.6	110.6	127.6	145.0	162.6

TABLE IV.—CAST METAL CYLINDERS.*

Diam.—Ins.	Iron.—lbs.	Copper.—lbs.	Brass.—lbs.	Lead.—lbs.
1	2.5	3.0	2.9	3.9
2	9.8	12.0	11.4	15.5
3	22.1	27.0	25.8	34.8
4	39.3	47.9	45.8	61.9
5	61.4	74.9	71.6	96.7
6	88.4	107.8	103.0	139.3
7	120.3	146.8	140.2	189.6
8	157.1	191.7	183.2	247.7
9	198.8	242.7	231.8	313.4
10	245.4	299.5	286.2	387.0

TABLE V.—SPECIFIC GRAVITY AND WEIGHT OF MATERIALS.

METALS.	Specific Gravity.	Wt. of 1 cubic foot.	Wt. of 1 cubic inch.
	oz.	lbs.	oz.
Antimony, cast	6702	418.9	3.878
Arsenic	5763	360.2	3.335
Bismuth, cast	9822	613.9	5.684
Brass, cast	8396	524.8	4.859
Brass, wire	8544	534.0	4.944
Bronze	8222	513.4	4.753
Cobalt, cast	7811	488.2	4.520
Copper, cast	8788	549.3	5.086
Copper, sheet	8915	557.2	5.159
Copper, wire	8878	554.9	5.136
Gold, pure	19258	1203.6	11.161
Gold, hammered	19362	1210.1	11.205
Gold, standard	17647	1102.9	10.230
Gun metal	8784	549.0	5.083
Iron, bars wrought	7786	486.6	4.506
Iron, cast	7207	450.4	4.171
Lead, cast	11352	709.5	6.569
Mercury, solid	15632	977.0	9.046
Mercury, fluid	13568	848.0	7.852
Nickel, cast	7807	487.9	4.518
Platinum, pure	19500	1218.8	11.285
Platinum, hammered	20336	1271.0	11.767
Silver, pure	10474	654.6	6.061
Silver, hammered	10511	656.9	6.083
Silver, standard	10534	658.4	6.096
Steel, tempered	7818	488.6	4.524
Steel, soft	7833	489.6	4.533
Tin, cast	7291	455.7	4.244
Type metal	10450	653.1	6.047
Zinc, cast	7190	449.4	4.161

* The cylinders are solid, each one foot in length

TABLE VI.—SPECIFIC COHESION AND STRENGTH OF METALS.

In the following table of *specific cohesion*, the cohesion of *plate glass* is assumed as unity. If any of the numbers in this table be multiplied by 9240, the product will express the force in pounds, which would tear asunder a bar of the corresponding material, of one inch square of transverse section. Thus, the specific cohesion of steel, razor temper, is 15.927; whence the extreme cohesion of a bar one inch square is $15.927 \times 9240 = 147{,}165.48$ pounds.

	Specific cohesion.
Antimony, cast	0.113
Bismuth, cast	0.345 to 0.319
Copper, wire	6.606
" cast, Barbary	2.396
" " Japan	2.152
Gold, wire	3.279
" cast	2.171
Iron, wire	12.004 to 9.108
" bar	8.964 to 5.839
" " best quality	7.006
" " German, B R	9.880 to 6.514

	Specific cohesion
Iron, bar, Swedish, L	9.445 to 7.296
" " Liege	8.794 to 6.621
" " German, L	9.119 to 7.382
" " Spanish	8.685
" " Oosement	8.142 to 7.296
" " fine grained	5.306
" " medium fineness	3.618
" " coarse grained	2.172
" cast, French	7.470 to 4.000
" " German	7.250
" " English	5.520 to 4.334
Lead, milled	0.354
" wire	0.334 to 0.270
" cast, English	0.094
Platinum, wire	5.995 to 5.625
Silver, wire	4.090
" cast	4.342
Steel, razor temper	15.927
" soft	12.739
Tin, wire	0.757
" cast, English block	0.706 to 0.565
" " Banca	0.391
" " Malacca	0.342
Zinc, wire	2.394
" patent sheet	1.762
" cast, Goslar	0.312 to 0.286

TABLE VII.—DIRECT COHESION OF METALS.

THE numbers in this table of experiments express the direct cohesion of bars one inch square in tons, of 2240 pounds.

			Tons.	lbs
Iron bar, cast horizontally			8	32
" " vertically			8	69
Cast steel, previously tilted			59	93
Blistered steel, reduced by hammer			59	43
Shear " " "			56	97
Swedish iron " "			32	15
English " " "			24	93
Hard gun metal			16	23
Wrought copper, reduced by hammer			15	8
Cast " " "			8	51
Fine yellow brass			8	01
Cast tin			2	11
Cast lead			0	81
Wrought iron, mean of 26 experiments,				
		Brunel	31	20
" " 9		*Brown*	29	25
" " 8		*Telford*	25	00
Iron cable, " 13		*Brown*	21	25

TABLE VIII.—RESISTANCE OF METALS TO PRESSURE.

IN this table of experiments the number of pounds are the weights required to crush cubes of one-quarter inch in the edge.

	lbs.
Iron, cast vertically . . .	11136
" " horizontally . . .	10114
Copper, cast	7318
" wrought	6440
Brass	10304
Tin, cast	966
Lead, cast	483

TABLE IX.—RESISTANCE OF METALS TO TORSION.

THIS table of experiments by *Brandreth*, exhibits only the relative resistance to *torsion*, that of lead being assumed as unity.

	lbs.
Cast steel	19.56
Shear steel	17.06
Blister steel	16.69
English iron	10.13
Swedish iron	9.50
Hard gun metal	5.00
Fine yellow brass	4.69
Copper	4.31
Tin	1.44
Lead	1.00

GOLD AND SILVER SOLDERS.

Hard Solder for Gold is prepared from gold and silver, or from gold and copper, or from gold, silver, and copper.

Gold Solder.—66.6 parts of gold, 16.7 parts of silver, and 16.7 parts of copper.

Hard Solder for Silver.—Equal parts of silver and brass; but made easier of fusion by the admixture of one-sixteenth of zinc.

Another Silver Solder.—19 parts fine silver, 1 part copper, 10 parts brass.

Another Silver Solder.—66.6 parts silver, 30.4 parts copper, 3.4 parts brass.

BRASS SOLDER.

BRASS mixed with a sixth, an eighth, or even one-half of zinc.

Another Brass Solder.—12 pounds copper, and 11 pounds of zinc.

METHOD OF SOLDERING GOLD AND SILVER.

AFTER the solder is cast into an ingot, it would be more ready for use if you were to draw it into small wire, or flat it between two rollers. After that cut it into little bits, then join your work together with fine soft iron wire, and with a camel's-hair pencil dipped in borax, finely powdered and

well moistened with water, touch the joint intended to be soldered, placing a little solder on the joint. Apply it on a large piece of charcoal, and with a blow-pipe and lamp blow upon it through the flame until it melts the solder, and it is done.

TO CLEANSE SILVER AFTER IT IS SOLDERED.

MAKE it just red hot, and let it cool; then boil it in alum water, in an earthen vessel, and it will be as clean as when new.

TO CLEANSE GOLD AFTER IT IS SOLDERED.

PUT it through the same process as silver, but, instead of alum-water, boil it in wine and sal-ammoniac.

SILVER-SOLDER FOR JEWELLERS.

19 dwts. of fine silver, 1 dwt. of copper, and 10 dwts. of brass.

TRINKET COMPOSITION.

75 parts gold, 25 parts copper, and a little silver

SILVER-PLATE AND MEDAL ALLOY.

95 parts silver, and 5 parts of copper.

GOLD COIN OF AMERICA ALLOY.

90 parts gold, 2.5 silver, and 7.5 copper.

SOLDER FOR IRON.

NOTHING here is necessary but good tough brass, with borax, applied, mixed with water to the consistence of cream.

AUTOGENOUS SOLDERING.

AUTOGENOUS soldering takes place by the fusion of the two edges of metals themselves without interposing another metallic alloy as a bond of union. This is accomplished by directing a jet of burning hydrogen gas from a blow-pipe provided with a Daniell's cock upon the surfaces or edges to be soldered together. The hydrogen gas is developed by the action of hydrochloric (muriatic) acid upon zinc shavings, the generated gas being collected in strong vessels or bags of stout canvas, made gas-proof by several coats of rubber varnish. The Daniell's cock is so arranged that the gas is mixed with atmospheric oxygen only at the place where it is to be burnt, thus avoiding all danger of explosions. In soldering by the autogenous process, the works are first prepared and scraped clean as usual. The hydrogen gas is then ignited, and after regulating the flame, air is admitted until the flame assumes a fine pointed character, with which the work is united. This method of soldering is occasionally employed in making small additions to old castings, and also in repairing trifling holes and defects in new ones.

SOFT SOLDERS.

TIN and lead in equal parts. Easier of fusion still is tin, lead, and bismuth, in equal parts; or one or two bismuth, one lead, and one tin, easier still.

For soft soldering brass, tin-foil makes a fine juncture, applied between the joints, care being taken to avoid too much heat. This is most excellent for fine brass work. The tin-foil must be moistened in a strong solution of sal-ammoniac.

A SOLDER FOR LEAD.

2 parts lead and 1 part tin. Its goodness is tried by melting it and pouring the bigness of a dollar piece upon the table; for if it be good there will arise little bright spots in it. Apply rosin when you use the solder.

PLUMBER'S SOLDER.

1 part bismuth, 5 parts lead, and 3 parts tin, forms a compound of great importance in the arts.

COMPOSITIONS OF PEWTER.

1. 100 parts tin, 17 parts of antimony; *the French add a little copper.*

2. 12 pounds of tin, 1 pound of antimony, 4 ounces of copper.

3. 7 pounds of tin, 1 pound of lead, 6 ounces copper, 2 ounces zinc. *Melt the copper first.*

WHITE METAL.

10 ounces lead, 6 ounces bismuth, and 4 drachms of antimony; or, 2 pounds of antimony, 8 ounces of brass, and 10 ounces of tin.

MOSAIC MIXTURE.

EQUAL parts of tin, bismuth, and mercury, forms a metal used for various ornamental purposes.

SILVERY-LOOKING METAL.

A VERY fine silvery-looking metal is made from 100 parts tin, 8 parts antimony, 1 part bismuth, and 4 parts copper.

METAL FOR FLUTE VALVE KEYS.

4 ounces of lead and 2 ounces of antimony.

GERMAN TITANIUM.

2 drachms of copper, 1 ounce of antimony, and 12 ounces of tin.

SPANISH TITANIUM.

8 ounces of scrap iron or steel, 1 pound c
mony, and 3 ounces of nitre.

The iron or steel must be heated to wh
and the antimony and nitre added in small p
Two ounces of this compound are sufficient to
one pound of tin.

BRITANNIA METAL.

4 ounces of plate brass, 4 ounces of tin
fused add 4 ounces of bismuth, and 4 ounces
timony. This composition is added at discr
melted tin.

COLUMBIA METAL.

4½ pounds of tin, ½ pound of bismuth, ½ p
antimony, and ½ pound of lead; or, 100 po
tin, 8 pounds of antimony, 1 pound of bismu

antimony, 25 pounds of lead, and 5 pounds of iron Many add tin, copper, and brass; while some make their types from 8 parts lead, to 1 of antimony.

GERMAN SILVER.

1. 25 parts nickel, 20 parts zinc, and 60 parts copper. If for casting add 3 parts of lead.

2. 16 parts copper, 8 parts zinc, and 3½ parts nickel.

3. 8 parts of copper, 3½ parts of zinc, and 2 parts of nickel.

4. 28 parts copper, 13 parts zinc, and 7½ parts nickel.

5. Copper, 8 parts; zinc, 3½ parts; nickel 3 parts.

This last is a very beautiful compound. It has the appearance of silver a little below standard. By some persons it is even preferred to the more ex-

pensive compound. Manufacturers are strongly recommended not to use a metal inferior to this.

SPECULUM METAL.

1. Copper, 64 parts; grain tin, 29 parts. Melt the metals separately, under a little black flux. Incorporate thoroughly by stirring with a wooden spatula; then run the metal in the mould, so that the face of the intended *mirror* may be downwards.

2. Copper, 32 parts; tin, 14 parts; arsenic, 2 parts. A very good metal.

3. Copper, 32 parts; tin, 13½ parts; arsenic, 1½ parts.

4. Copper, 32 parts; tin, 15 parts; arsenic, 2 parts. Better than 2 and 3.

5. Copper, 32 parts; tin, 15 parts; brass, 1 part; silver, 1 part; arsenic, 1 part. A most excellent metal, and by far the whitest, hardest, and most reflective metal I have ever yet met with.

6. Copper, 6 parts; tin, 2 parts; arsenic, 1 part Sir Isaac Newton's mixture. It is a compact metal enough, but very yellow when polished.

7. Copper, 3 parts; tin, 1½ parts. Compact, and whiter than the last.

8. Brass, 6 parts; tin, 1 part. Compact, but too yellow.

9. 2 parts of 7th composition, and 1 part of 8th. Compact, but much too yellow when polished. 7. 8, and 9, are experiments by Professor Molyneux, F. R. S.

10. Copper, 32 parts; tin, 2 parts; arsenic, 1 part. A pretty good metal, but polishes too yellow Professor Mudge's composition.

REMARKS.

In melting arsenic, nitre is a good flux for fixing it with other metals.

In using iron filings in your compositions, use corrosive sublimate (viz. chloride of mercury) for fixing it.

Powdered flint glass also makes a most excellent flux for copper, tin, and arsenic.

No. 5. This metal, when broken, should appear of a bright, glassy, and quicksilver complexion. If it appears hard and of a dead white, more tin must be added. The copper will sometimes take sixteen ounces of tin, if it is very pure. If it appears bluish and rough, more copper or brass must be added.

It is somewhat singular that arsenic, though particularly recommended by Sir Isaac Newton, Dr. Olynthus Gregory, and others, for giving homogeneity to metallic compositions, should be so hastily thrown aside by the founders. This imprudent disuse of it, I can only attribute to the disagreeable fumes or vapours, which arise when it is introduced into the crucible, to the melted mixture, which may produce disagreeable effects upon the operators, if

proper care be not taken to prevent them from being received into the lungs. All the precaution necessary, is to bruise the *arsenic* coarsely, and introduce it into the crucible with a pair of tongs, having tied it up in a piece of paper, giving it then a stir with a wooden spatula made of birch, during which time retaining your breath—avoid it till you can see no more vapours arise from the crucible, when the metal will be ready to pour.

The common black flux is made of two parts of tartar, and one of nitre.

I have always found from adding a small quantity of arsenic, viz., from one-half ounce to one ounce to the pound of metal, that it would considerably improve even porous metal, and make it harder, likewise, as well as whiter.

In making speculums, the casting should be taken from the mould red-hot, and put into a quantity of hot ashes to anneal it, or else it will break in the sand. Let it remain in the ashes till the whole becomes cold.

Professor Nevil Masculyne, speaking of arsenic, says—I have been assured by two ingenious experimental philosophers that the fumes of arsenic, even when the garlic smell is very strong, are not in the least prejudicial to the lungs.

A careful study of the above remarks will be of inestimable advantage to the practical brass founder, saving him both loss of work, as well as loss of time.

PLATINA.

MIRRORS for telescopes, &c., are made of platina, of exquisite beauty. The Spaniards are in the habit of mixing it with iron, in order to form gun-barrels, which are said never to rust, and which are much stronger than iron barrels alone, as it gives to the iron a remarkable toughness. It forms a valuable coating for copper and iron, and may hereafter become precious for the formation of *coins* and *medals*.

Platina, in its malleable state, may be cut with a knife; but with steel it forms an alloy not to be touched with a file.

The nitro-muriatic acid is the proper solvent for platina.

ON THE PROPERTIES OF ARSENIC.

ARSENIC is a brittle metal, and, in the recent fracture, of a lively bright colour, between tin-white and lead-gray; but on exposure to the air it soon loses its metallic lustre, and turns prismatic, dull, and at last black. Its specific gravity is, according to Professor Mudge, between 8.310 and 5.763, according to its texture.

Its hardness surpasses that of copper, but its ductility is so little, and it brittleness so great, that it is readily converted into a powder by the hammer. It is entirely volatilized when heated to 356° Fahr. It sublimes in close vessels, and then crystallizes in tetrahedra, or octahedra. When heated with the excess of air, it emits a strong smell of garlic, and burns with a bluish white flame. It combines with sulphur by fusion. It unites to phosphorus, and combines with most of the metals

Besides giving a white colour to copper, it renders many of the ductile metals brittle. When mixed with hyper-oxygenated muriate of potash, it detonates strongly by the stroke of a hammer. It is soluble in hydrogen gas by heat. It does not decom-

pose water alone; it decomposes sulphuric acid by heat. The nitric and nitrous acid oxidate it rapidly. The muriatic acid attacks it with heat. The oxygenated muriatic acid (now termed chlorine), when in a gaseous state, inflames it instantly. It is nearly unalterable by the fluoric, boracic, phosphoric, and carbonic acids. It unites with alkaline sulphurets and hydro-sulphurets. It is a deadly poison.

If you insert a little arsenic, reduced to fine powder, between two polished plates of copper, and bind closely together with *iron wire*, and heat them, the inner surfaces of the copper plates will be rendered white by the arsenic.

Experiment No. 1. *Experimental proofs of the properties of arsenic. Arsenic burns and is volatilized by heat.*—Introduce into a crucible, made red-hot in a coal fire, a small quantity of arsenic, and it will begin to burn and become volatilized. If this crucible be covered with another, and the joinings luted with clay, the arsenic will be found in the upper one in brilliant crystals.

Experiment No. 2.—The union of arsenic with copper may likewise be effected by fusing 1 part of arsenic with 4 of copper, in a common crucible.

The alloy produced is a white metal. It is necessary in this experiment to cover the substances in the crucible with common salt, to prevent the action of the air.

FONTAINEMOREAU'S NEW ALLOYS OF ZINC, A SUBSTITUTE FOR BRONZE, COPPER, AND BRASS.

An invention of a new alloy of zinc, with small proportions of other metals, found to possess very peculiar advantages, has lately been introduced into England, where it has been patented in the name of M. Fontainemoreau. It is likely to prove of great utility in the manufacture of machinery, and in castings relating to the fine arts. As a substitute for copper and bronze it already bids fair to be extensively adopted.

The proportions of metals which have been found most advantageous in forming varieties of the alloy, after very numerous and extensive experiments, are as follows:—

No. 1. Zinc, 90 parts; copper, 8 parts; cast iron, 1 part; lead, 1 part; 100 parts.

No. 2. Zinc, 91 parts; copper, 8 parts; lead, 1 part; 100 parts.

No. 3. Zinc, 92 parts; copper, 8 parts; 100 parts.

No. 4. Zinc, 99 parts; copper, 1 part; 100 parts.

No. 5. Zinc, 97 parts; copper, 2½ parts; cast iron, ½ part; 100 parts.

No. 6. Zinc, 97 parts; copper, 3 parts; 100 parts.

No. 7. Zinc, 99½ parts; cast iron, ½ part; 100 parts.

No. 8. Zinc, 91½ parts; copper, 8 parts; cast iron, ½ part; 100 parts.

The proportions stated of any of these metals may be slightly varied, so long as by such variation the alloy is not made too brittle, or too soft. For instance, the proportion of copper may be varied from about 1 part to about 12 parts, in every hundred; but any greater proportion of copper than this, and less than that used in forming common brass, would make the alloy brittle. The proportion of cast iron may be varied from about one-quarter of a part, to about two parts in every hundred. The proportion of lead may be varied from about one, to about twenty-four parts in every hun-

dred parts: but the presence of some third metal is necessary to produce a proper combination of the zinc and lead. Instead of pure copper, or any other of the simple metals before to be used, brass, or the other alloys formed of these metals, may be used. But where this is done, the quantity of copper and the simple metals contained in such alloys must be taken into account in calculating the relative proportions of simple metals which the new alloy is to contain in reference to the tables of component parts.

The principal object of the addition of the small quantities of copper, cast iron, and lead to the larger proportions of zinc, is to change the manner of the crystallization of the zinc after it has been fused and set to cool.

The new alloys are of a closer texture, more homogeneous, and malleable, than simple zinc, and some kinds of iron; are less liable to oxidation, and of a much finer grain than zinc—somewhat resembling that of steel, especially when the alloys are rolled. They are also easier filed than either zinc, copper, or brass, and the filings do not stick in and clog the file.

N. B. By casting the new alloys in metallic moulds, their *hardness* and homogeneity is increased,

and a sort of *temper* is imparted to them, resembling or approaching to steel.

For the purpose of rendering the alloys which are of a silvery-gray colour, perfectly suitable as substitutes for copper, bronze, brass, and other metals, the colour proper to the metals of which they are intended to be substitutes, is imparted to them by means of any solution of copper. The hydrochlorate of copper is found to answer best—

Firstly.—For giving the alloys a blackish-bronze colour, they are treated with a solution of the salt of copper, diluted with a considerable quantity of water, and a small quantity of nitric acid may be added.

Secondly.—To impart a red or copper colour, add to the solution of salt of copper, liquid ammonia, and a little acetic acid. The salt of copper may be dissolved in the liquid ammonia.

Thirdly.—To impart a brass, or antique bronze colour, either of the three following means may be adopted: 1. A solution of copper, with some acetic acid. 2. The means before described for copper colour, with a large proportion of liquid ammonia. 3. Water acidulated with nitric acid, by which beautiful bluish shades may be produced. It must be observed, however, that this last process can only

be properly employed on the alloys which contain a portion of copper.

In either of these methods of colouring, a solution of sal-ammoniac may be substituted for the liquid ammonia. The quantities of each ingredient have not been stated, as these depend upon the nature of the alloy, the shade or hue desired, and the durability required.

The blackish-bronze colour may be superadded to the red or copper colour, whereby a beautiful light colour is produced on the prominent parts of the article bronzed, or on the parts from which the blackish-bronze colour may have been rubbed off.

These new alloys may be used as substitutes for various metals now in general use, such as iron, in various parts of machinery; iron, lead, tin, or copper, in pipes and tubes, and bronze, brass, and copper, in machinery and manufactories, as well as for most of the other purposes for which more expensive metals are employed.

SOME MODERN BRONZES.

Aluminium bronze. Commercial pig copper almost invariably contains more or less dissolved cuprous oxide and occluded gases. The presence of these impurities tends to decrease the ductility of the metal, and their removal produces an astonishing increase in the tensile strength and general ductility.

In this simple fact lies the secret of the excellent results obtained with the improved copper-alloys, known as aluminium bronze, phosphor bronze, manganese bronze, deoxidized copper, tempered copper, etc.*

The alloys of aluminium with copper show very different properties, according to the quantities of aluminium they contain. Alloys containing but little copper cannot be used for industrial purposes. With 60 to 70 per cent. of aluminium they are very brittle, glass hard and beautifully crystalline. With 50 per cent. the alloy is quite soft, but under 30 per cent. of aluminium the hardness returns.

The usual alloys are those of 1, 2, 5 and 10 per

*New Alloys by F. Lynwood Garrison, Journal of the Franklin Institute, Vol CXXXI.

cent. of aluminium, the best results being obtained with the latter. With small bars cast in sand, perhaps the best physical results obtained are: Elastic limit, 70,000 lbs. per square inch; tensile strength, 95,000 lbs. per square inch, with about 10 per cent. elongation. With rolled bars much better results have been obtained, more particularly as regards elongation. The modulus of elasticity of aluminium bronze is about 18,000,000 lbs.; specific gravity when cast about 7.56, when rolled about 7.89.

The structure of aluminium bronze is close and dense. The melting point varies somewhat with the amount of aluminium contained in the bronze, the higher grades melting at a somewhat lower point than the lower grades. The color of the 10 per cent. bronze is bright golden. The metal keeps its polish in the air, may be easily engraved, and can be soldered with hard solder.

In making aluminium copper alloys great attention must be paid to the quality of the copper used. Ordinary commercial copper may contain small amounts of antimony, arsenic or iron, which the aluminium can in no way remove, and which affect very injuriously the quality of the bronze. The aluminium bronzes seem to be extremely sensitive to the above metals, particularly to iron. This neces-

sitates the employment of the purest copper; electrolytic copper is sometimes used when not too high-priced, but Lake Superior copper is generally found satisfactory enough. Even the purest copper may contain dissolved cuprous oxide or occluded gases, and it is one of the functions of aluminium to reduce these oxides and gases, forming slag, which rises to the surface, and leaving the bronze free from their influences. If tin occurs in the copper it lowers very greatly the ductility and strength of the bronzes, but zinc is not so harmful.

Care should also be taken as to the purity of the aluminium used, though its impurities are not so harmful as they would be if occurring in similar percentage in copper, since so much more copper than aluminium is used in these alloys. Yet the bronzes are so sensitive to the presence of iron that an aluminium with as small a percentage of this metal as possible should be used. The silicon in commercial aluminium is not so harmful as the iron, but it does harden the bronze considerably and increases its tensile strength. The purest aluminium alloyed with the purest copper always produces the highest quality of bronze.

For preparing the bronzes the following directions are given: Melt the copper in a plumbago crucible

and heat it somewhat hotter than its melting point. When quite fluid and the surface clean, sticks of aluminium of a suitable size are taken in tongs and pushed down under the surface, thus protecting the aluminium from oxidation. The first effect is necessarily to chill the copper more or less in contact with the aluminium, but if the copper was at a good neat to start with, the chilled part is speedily dissolved and the aluminium attacked. The chemical action of the aluminium is then shown by a rise of temperature which may even reach a white heat Considerable commotion may take place at first, but this gradually subsides. When the required aluminium has been introduced, the bronze is let stand for a few minutes and then well stirred, taking care not to rub or scrape the sides of the crucible. By the stirring, the slag, which commences to rise even during the alloying, is brought almost entirely to the surface. The crucible is then taken out of the furnace, the slag removed from the surface with a skimmer, the metal again stirred to bring up what little slag may still remain in it, and is then ready for casting. It is very injurious to leave it longer in the fire than is absolutely necessary. No flux is required, the bronze needing only to be covered with charcoal powder. The particular point to be

attended to in melting these bronzes is to handle as quickly as possible when once melted.

The manufacture of aluminium-bronzes on a large scale, as carried on by the Cowles Electric Smelting and Aluminium Company, is as follows: The furnace used consists of a brick box 1 foot wide, 5 feet long and 15 inches deep. From opposite ends enter two immense electrodes, that are really electric-light carbons, 3 inches in diameter and 30 inches long. These are partly contained in pipes that, in turn, pass through stuffing boxes in the ends, to exclude the air and, at the same time, admit of adjusting the electrodes.

To protect the walls of the furnace from the intense heat, it is lined with finely-powdered charcoal, which, having been first washed in a solution of lime-water, retains its non-conductivity even after the particles have been partially converted into graphite by heat.

The bottom of the furnace is now lined to a depth of two or three inches with this fine, prepared charcoal, and by means of a sheet-iron gauge, the walls of the furnace are covered with charcoal to the thickness of two inches.

The charge, consisting of about 25 lbs. of corundum, 12 lbs. charcoal and carbon, and 50 lbs. of

granulated copper, is placed about the electrodes to within a foot of each end of the furnace. A layer of coarsely-broken charcoal is now spread over the charge, and the sheet-iron gauge withdrawn. The coarse charcoal on top allows the escape of carbonic oxide gas formed during the process. An iron cover, lined with fire-brick, is luted on to prevent the entrance of air.

The charge is now prepared, and the furnace ready to be connected with a large Brush dynamo, capable of producing ninety horse-power of electric energy. In the circuit between the dynamo and furnace is an ammeter, designed to register from 50 to 20,000 ampères of current, which is controlled by a large resistance-box, as the ends of the electrodes may at first be too close together to make it safe to start the dynamo. By watching the ammeter and moving the electrodes, the resistance-box can be taken gradually out of circuit without producing a "short circuit" at the beginning of the operation. In about ten minutes, after the copper about the electrodes has become melted, the latter are slowly moved apart until the current becomes steady. It is now increased to about 1300 ampères and fifty volts. Carbonic oxide begins to escape from the orifices made in the top, and burns in two white

plumes of flame. By regulating the distance between the electrodes, the current is kept constant for about 5 hours, and all parts of the charge are brought into the reducing zone.

When the operation is completed, a resistance is placed in the box, and the current is switched into another furnace charged in a similar manner. The product is an alloy of copper, containing 15 to 30 per cent. of aluminium, and having a beautiful silver color when broken. The copper performs no part in the reduction, but is employed to absorb the aluminium, which would otherwise be converted into a carbide.

This alloy is now melted in an ordinary crucible furnace and run into ingots, which, after being analyzed, are re-melted, and sufficient copper added to produce the standard bronzes.

Two runs from the furnace described will produce about 100 pounds, containing about 15 per cent. of aluminium.

When a 10 per cent. aluminium bronze is made by simple mixing of ingredients, it is brittle, and does not acquire its best qualities until having been cast several times. After three or four meltings it reaches a maximum, at which point it may be melted several times without sensible change. As it cools

rapidly, large castings require some care to prevent cracking, so numerous runners and a large feeding-head should be employed. The 10 per cent. bronze fuses at about the temperature of brass containing 33 per cent. zinc, and the 5 per cent. melts at a somewhat higher temperature. The former should be poured as cool as possible to produce sharp castings, and should be kept covered with charcoal up to the moment of pouring. Considerable care must be taken in the preparation of "risers," so that the metal will free itself of impurities. The metal can conveniently be freed from slag or other impurity when pouring into the mould by the following method: A supplementary pot or crucible, with a hole in the bottom, is secured over the pouring-gate of the mould. This hole is first plugged up by a carbon or iron rod heated to redness, and the pot is filled with the melted metal before the plug is withdrawn. This allows the oxide and slag to rise to the surface, and admits only pure metal to the mould. It also prevents the oxidation that a stream of metal would suffer in pouring through the air to the "pouring gate," as is often practiced.

The shrinkage of 10 per cent. aluminium bronze in casting is about 50 per cent. more than ordinary brass.

Aluminium bronze forges similar to the best Swedish iron, but at a much lower temperature. It works best at a cherry red; if this is much exceeded, the metal becomes "hot short," and is easily crushed. The temperature for rolling is a bright red heat, and it is a curious fact that, if the metal were forged at the temperature it is rolled, it would be smashed to pieces. If the temperature in the ordinary muffle in which it is heated be allowed to rise too high, the bronze will frequently fall apart by its own weight. When in the rolls it acts very much like yellow Muntz metal. As it loses its heat much more rapidly than copper or iron, it has to be annealed frequently between rollings.

An incident that occurred in the French postage stamp manufactory, Paris, may here be cited as illustrating some of the peculiar properties of aluminium bronze. Great trouble was experienced to procure a suitable die-plate to place beneath the needles of a machine used for perforating sheets of postage stamps. At every blow, the needles passed through the holes in the die-plate, and as there were 300 needles making rapid strokes, about 180,000,000 holes were made per day. With this usage brass-plates wore out in a day, and even steel-plates were speedily destroyed. A plate of aluminium-bronze being substituted, lasted for months without renewal.

Delta metal. This metal was patented, in 1882, by Alexander Dick, but it has exactly the same composition as sterro-metal, which was introduced some years ago by Baron Rosthorn, of Vienna. It is composed of about 60 parts of copper, 34 to 44 of zinc, 2 to 4 of iron, and 1 to 2 of tin.

The peculiarity of this and similar alloys is the content of iron, which appears to have the property of increasing the strength to an unusual degree. In making delta metal the iron is previously alloyed with zinc in known and definite proportions. When ordinary wrought-iron is introduced into melted zinc, the latter readily dissolves or absorbs the former, and will take it up to the extent of about 5 per cent. or more. By adding the zinc-iron alloy thus obtained to the requisite amount of copper, it is possible to introduce any definite quantity of iron up to 5 per cent. into the copper alloy. Hiorns states that the inventor uses a small amount of phosphorus in combination with the copper to avoid the oxidation when the alloy is remelted. In some cases he uses tin, manganese and lead to impart special properties. The inventor claims that by this process the iron is chemically combined in the brass and bronze.

The advantages claimed for delta metal are great strength and toughness. It produces sound castings

of close grain. It can be rolled and forged hot, and can stand a certain amount of drawing and hammering when cold. It takes a high polish, and when exposed to the atmosphere tarnishes less than brass.

When cast in sand, delta metal has a tensile strength of about 45,000 lbs. per square inch and about 10 per cent. elongation; when rolled, a tensile strength of 60,000 to 75,000 lbs. per square inch and elongation of from 9 to 17 per cent. on bars 1.128 inch in diameter and 1 inch area.

Delta metal can be forged, stamped and rolled hot. It must be forged at a dark cherry-red heat, and care taken to avoid striking when at a black heat.

Delta metal as manufactured by the "Deutsche Delta-Metall Gesellschaft" is composed as follows:

Constituents.	Cast Per cent.	Wrought Per cent.	Rolled Per cent.	Hot punched Per cent.
Copper	55.94	55.80	55.82	54.22
Lead	0.72	1.82	0.76	1.10
Iron	0.87	1.28	0.86	0.99
Manganese	0.81	0.96	1.38	1.09
Zinc	41.61	40.07	41.41	42.25
Nickel	Trace	Trace	0.06	0.16
Phosphorus . . .	0.013	0.011	Trace	0.02
	99.963	99.941	100.29	99.83

Deoxidized bronze. This alloy is manufactured by the Deoxidized Metal Company of Bridgeport,

Conn. It resembles phosphor-bronze somewhat in composition, and also delta metal, in containing zinc and iron. The following analysis by Mr. Jas. S. de Benneville gives its average composition:

Copper	82.67
Tin	12.40
Zinc	3.23
Lead	2.14
Iron	0.10
Silver	0.07
Phosphorus	0.005
	100.615

It seems probable that some deoxidizing flux containing phosphorus, similar to that employed in the manufacture of phosphor-bronze is used in the manufacture of this alloy. Deoxidized bronze is largely used for wood-pulp digesters, as it is found to resist the action of sodium hyposulphite and sulphurous acid remarkably well.

Deoxidized bronze wire has a tensile strength in the neighborhood of 150,000 lbs. per square inch. The deoxidized copper wire made by the Deoxidized Bronze Company has a tensile strength of 70,000 lbs. per square inch; and the deoxidized copper sheets, a tensile strength of from 30,000 to 50,000 lbs. per square inch.

Manganese bronze. This alloy has been used very extensively for casting propeller blades, both in this country and abroad. When cast in sand it has an average elastic limit of 30,000 lbs. per square inch, tensile strength about 60,000 lbs. per square inch with an elongation of 8 to 10 per cent. When rolled the elastic limit is about 80,000 lbs. per square inch, tensile strength 95,000 to 106,000 lbs. per square inch, and an elongation of 12 to 15 per cent.

For several years past manganese bronze appears to have been made in large quantities by Mr. P. M. Parsons of the Manganese Bronze Company, Deptford, England, the manganese being added in the form of ferro-manganese. A portion of the manganese in the alloy thus added is utilized in deoxidation, while the remainder, together with the iron, becomes permanently combined with the copper. The manganese once alloyed with the copper is not driven off by remelting, but usually the quality of the bronze is improved by remelting.

Ferro-manganese is composed of manganese, 75 parts, and iron, 75.

An alloy of copper and manganese, the so-called *cupro-manganese*, consisting of copper, 70.5 parts; manganese, 25, and coal, 0.5, is recommended as an

addition to bronze. Of this composition, an addition of 2⅔ per cent. suffices for most cases. The process is very simple. After melting the bronze-masses, the metal-bath is covered with pulverized charcoal, and the pieces of cupro-manganese, previously weighed and reduced to small pieces, are allowed slowly to slide into the crucible. Fusion takes place instantaneously, but the crucible is for a few moments to be replaced upon the fire, in order to somewhat increase the temperature reduced by the addition of the cold pieces of metal. In pouring out proceed in the ordinary manner. To enclose the oxide of manganese formed by this process, add to the charcoal, with which the metal-bath is covered, about one-half its quantity of pure carbonate of potash.

Alloys prepared with the assistance of cupro-manganese, which are especially valuable for technical purposes, have the following composition:

	Parts.			
	I.	II.	III.	IV.
Copper	77	60	65	60
Manganese	25	25	20	20
Zinc	—	15	5	—
Tin	—	—	—	10
Nickel	—	—	10	10

Phosphor-bronze. In 1868 Montefiore and Kün-

zel, of Liège, Belgium, observed that the tin in bronze progressively decreases by oxidation during smelting, the tin oxide going partly into the slag and being partly dissolved in the melted metal, so that bronze originally composed of 10.10 per cent. tin and 89.90 copper, after the fourth melting contained only 8.52 tin and 91.48 copper. It was found that poling (stirring up the metal with a stick of green wood) eliminated the oxide combined with copper, but had no effect on the tin-oxide. Künzel then tried the introduction of a little phosphorus, or "phosphoret of tin or copper," into the mass, with the desired result. Bars cast from the same crucible of metal under the three conditions named gave the following results:

Condition of the mass of metal.	Resistance.		Lengthening until Rupture.
	Absolute lb. per square inch.	Elastic lb. per square inch.	Per cent.
Old bronze	22.982	17.020	2.0
" poled	24.922	17.709	2.8
" deoxidized with phosphorus.	33.916	19.300	6.8

Other experiments in phosphorizing alloys of copper, nickel, manganese and iron were not satisfactory, nor was that of using sodium instead of phosphorus as a deoxidizer. The action of phosphorus

in bronze is (1) to eliminate the oxides, and (2) to make the tin capable of assuming crystalline structure, thus increasing the homogeneity of the alloy, and thereby its elasticity and absolute resistance. Among other properties, phosphor-bronze emits sparks under friction less readily than gun metal or copper. It is peculiarly adapted for friction bearings; is easily rolled into sheets, and is very tough in that form. In sea-water it oxidizes at about one-third the rate of copper.

The following are Kirkaldy's figures for tenacity and ductility of phosphor-bronze wire No. 16, Birmingham gauge:

Phosphor-bronze Wire, No. 16.

Materials.	Load at fracture.				Elongation. Length 5 inches	No. of twists before breaking.	
	Unannealed.		Annealed.				
	Per sq. mm.	Per sq. inch.	Per sq, mm.	Per sq. inch.	Per cent.	Unannealed	Annealed
Phosphor-bronze of several proportions.	72.3 kilos	46 tons	34.7 kilos	22 tons	37.5	6.7	80
	85.1 "	54 "	33.6 "	21.3 "	34.1	22.3	52
	85.2 "	54.1 "	37.5 "	23.8 "	42.4	13.0	124
	97.7 "	62.1 "	42.8 "	27.2 "	44.9	17.3	53
	112.2 "	71.2 "	41.7 "	26.5 "	46.6	17.3	66
	106.3 "	61.6 "	45.4 "	28.9 "	42.8	15.0	60

Cast Phosphor-bronze.

Reduction of section.	Elastic limit.		Ultimate resistance.	
Per cent.	Per sq. mm.	Per sq. inch.	Per sq. mm.	Per sq. inch.
8.4	16.65 kilos	10.6 tons	37.0 kilos	23.5 tons
1.5	17.38 "	11.05 "	32.5 "	20.6 "
33.4	11.6 "	7.2 "	31.3 "	19.9 "

The content of phosphorus is imparted to the bronze by an addition of copper phosphide or phosphide of tin, both these phosphides being sometimes used at the same time. They must be especially prepared, the best process being briefly as follows:

Copper-phosphide. A mixture of bone ash, silica, and carbon is placed in a crucible, and upon it a layer of granulated copper, which is in turn covered with the above mixture. The lid of the crucible is luted on. To make the mixture melt more readily, some carbonate of soda and glass may be added, or a mixture of pulverized milk glass with charcoal and powdered coke is used for lining and covering it. Take for example 14 parts of silica, 18 of bone ash, and 4 of powdered carbon. This is mixed with 4 parts of soda and 4 of powdered glass, stirred up with a little gum water, and used to line the crucible. When this is dry the copper is put in and covered with the same mass, and the whole is melted

at a bright-red heat. The copper obtained flows well, and has a reddish-gray color. It contains 0.50 to 0.51 per cent. of phosphorus.

According to another method copper-phosphide is prepared by adding phosphorus to copper sulphide solution and boiling, adding sulphur as the sulphide is precipitated. The precipitate is carefully dried, melted and cast into ingots. When of good quality and in proper condition, it is quite black.

Phosphide of tin is prepared as follows: Place a bar of zinc in an aqueous solution of chloride of tin, collect the sponge-like tin separated, and bring it moist into a crucible upon the bottom of which sticks of phosphorus have been placed. Press the tin tightly into the crucible and expose it to a gentle heat. Continue the heating until flames of burning phosphorus are no longer observed on the crucible. After the operation is finished a coarsely-crystalline mass of a tin-white color, consisting of pure phosphide of tin, is found upon the bottom of the crucible.

Phosphor-bronze is prepared by melting the alloy to be converted into it in the usual manner, and adding small pieces of copper phosphide and phosphide of tin.

The phosphorus may also be introduced into the bronze as follows: Stick a bar of the phosphorus into

a tube of pinchbeck, one end of which is hammered together and closed tightly. After the phosphorus is put in the other end is also closed. When the metal, which contains 32 parts of copper to 5 of zinc and 1 of tin, is melted, the tube charged with phosphorus is pushed down in it to the bottom of the crucible by means of bent tongs. The stick of phosphorus must be kept under water until it is to be introduced into the pinchbeck tube, when it must be carefully dried, as the presence of any moisture would be sure to cause the metal to spurt or fly about.

Another way of introducing the phosphorus is as follows: Get from a gas-fitter about 2 feet of iron pipe, with a bore a little larger than the sticks of phosphorus; make an iron plug to fit the bore, and then drive it down one end of the pipe until the space will hold the quantity of phosphorus you wish to mix in the metal. Make a plug of tin, about $\frac{1}{8}$ inch thick, to fit in the bore. Now introduce the phosphorus in the space formed by the iron plug, and just tap the tin plug into the end of the pipe with a hammer. Stir the pipe about in the melted metal; the tin plug soon melts, letting out the phosphorus in the bronze baths.

According to Thurston, five sorts of phosphor-bronze are considered to answer all requirements:

0. Ordinary phosphor-bronze of 2 per cent. of phosphorus.

1. Good phosphor-bronze of 2½ per cent. of phosphorus.

These two numbers are in all cases superior to ordinary bronze and steel.

2. Superior phosphor-bronze of 3 per cent. of phosphorus.

3. Extra phosphor-bronze of 3½ per cent. of phosphorus.

4. Maximum phosphor-bronze of 4 per cent. of phosphorus.

These three, according to Delalot, are superior to any other bronzes. Above No. 4 phosphor-bronze is useless, below No. 0 it is inferior to common bronze and steel. Nos. 3 and 4 are comparatively unoxidizable.

Platinum-bronze. This bronze, which has been patented in various countries by Hélonis, of Paris, is described as follows: By alloying nickel with a small quantity of platinum it loses its oxidability and is not attacked by acetic acid. To prepare the alloy the nickel is melted, without flux, with the platinum and a certain quantity of tin. The following alloys are at present used:

	Nickel.	Platinum.	Tin.	Silver.
For knives, forks and spoons	100	1	10	—
" bells	100	1	20	2
" fancy articles	100	0.5	15	—
" field glasses	100	20	20	-

A non-oxidizable alloy is as follows: Nickel 60 parts, platinum 5 to 10, brass 120.

Silicon bronze. This alloy appears to have been invented, about 1881, by M. Weiller of Angouleme. In experimenting with phosphor-bronze wire for telegraphic and telephonic use, he found its conductivity was insufficient for telegraphic purposes, so he devised the alloy now called silicon bronze.

The silicon-copper compound, from which the silicon bronze is produced, is made by melting, in a graphitic crucible, a certain amount of copper with a mixture of fluor-silicate of potassium, glass, chloride of soda, carbonate of soda and chloride of calcium. It is claimed the silicon and sodium in this mixture absorb all the oxides present in the mass.

The action of the silicon on the copper is similar to that of phosphorus. It acts as deoxidizer and, the silica formed being an acid, is a valuable flux for any metallic oxides remaining unreduced.

Silicon bronze is chiefly used for telegraph and telephone wires, wire made from it having the same resistance to rupture as phosphor-bronze wire, but

with a much higher degree of electric conductivity. It also seems that, although wires made from this alloy are very much lighter than ordinary wires, they are of equal strength.

According to E. Van der Ven, phosphor-bronze has about 30 per cent., silicon bronze, 70 per cent., and steel 10½ per cent. of the electrical conductivity of copper.

The following shows the composition of silicon bronze used for wires:

Telephone Wire A.		*Telegraph Wire A.*	
Copper . . .	99.94 per cent.	Copper . . .	97.12 per cent.
Tin	0.03 "	Tin	1.14 "
Silicon . . .	0.02 "	Silicon . . .	0.05 "
Iron	trace	Iron	trace
Zinc	—	Zinc	1.62 "
	99.99 per cent.		99.93 per cent.

Steel-bronze. The ordnance-bronze known under this name is prepared in the Austrian arsenals, the method of melting and subsequent treatment in casting being kept secret. It is only known that the bronze contains 8 per cent. of tin, and that the casting is effected in cold iron moulds. The peculiarity of the process of manufacturing ordnance from steel-bronze (also called *Uchatius bronze* after its inventor) consists in the piece, after being finished to a certain extent, being subjected to a peculiar mechan

ical treatment. The calibre of the piece is made smaller than it is finally to be, and is then gradually enlarged to the required diameter by steel-cylinders with conical points being forced through the cavity with the assistance of hydraulic presses. In consequence of this peculiar treatment the cavity is, so to say, forged or rolled, the bronze acquiring the greatest power of resistance in those places which in firing are subjected to the greatest pressure.

Tobin bronze. This alloy is practically a sterro or delta metal with the addition of a small amount of lead, which tends to render copper softer and more ductile. According to the inventor's claims, the bronze can be forged and stamped at a red heat as readily as steel. Bolts and nuts can be forged from it by hand, and machinery when cold drawn. Its increased density and high elastic limit, and the facility with which it can be upset while hot make it well adapted for special purposes. The bronze should be forged only at a cherry-red heat and never be worked at a black heat. Analyses by Dr. Chas. B. Dudley:

	Pig Metal. Per Cent.	Test Bar (Rolled). Per Cent.
Copper	59.00	61.20
Zinc	38.40	37.14
Tin	2.16	0.90
Iron	0.11	0.18
Lead	0.31	0.35

ON ZINC AS A PROTECTIVE COVERING FOR IRON; AND THE ADAPTATION OF THE PROCESS OF ELECTRO-DEPOSITION FOR THAT PURPOSE. BY F. PELLATT, ESQ.

Read at the Institution of Civil Engineers, London.

THE object of this paper is to direct attention to the properties of zinc as a protecting coating to iron; to describe the processes already employed for this purpose; the reason of their failure; and the peculiar adaptation of the electro-deposition of the metal for the end desired.

It would be a needless waste of time to say anything regarding the superior value of iron as a material; but a few remarks respecting its chemical influences may not be misplaced.

The cause of iron becoming corroded is its superior affinity for oxygen. If the iron and water are both pure, this is not, indeed, found to be the case; but under ordinary circumstances, *neither* of these exist in a state of purity. The iron, therefore, owing to its own impurity, and that of the water, is subject

to a powerful destructive influence, which is best known to those most experienced in its use; and there is no circumstance in which we can place iron to be free from the action of water, it being present in the air and earth. So powerfully is this metal affected in the earth, or in contact with some salts, that it loses all its essential properties, and is converted into a substance so soft that it may be scratched by a finger nail. These facts render it of the utmost importance that some means be obtained for its protection, which, at the same time, will not interfere with the natural properties of the iron. The substances hitherto used for protecting iron are tin and paint. These, as lasting coatings, are not effective. The tin being electrically negative to the iron, renders it a means of destruction, instead of protection, when any part of the iron is exposed. By the laws of electricity, when metals are in contact, the *negative* metal is protected at the expense of the *positive*.

Circumstances, such as different chemical menstrua, may alter the relative electrical states of metals. But under all ordinary circumstances this rule holds good; and zinc being the positive metal, it becomes, in consequence, a protector to the negative metal, iron. This electrical property of zinc in

connexion with iron and other metals, has induced those to whom it was known, to recommend it as a coating. The difficulty hitherto has been the obtaining of zinc pure, and the application of it without injuring the texture of the iron.

From the known qualities of zinc, it has been lately much employed for various purposes, but has entirely disappointed the expectations formed from its properties. The reason of this is, that no zinc of commerce is pure, and that the impurities existing are destructive to it, from the electrical law we have alluded to. The impurities existing, more or less, in all zinc, are lead, iron, arsenic, and one or two other metals, all of which are electrically negative to zinc; the consequence being that every atom of impurity, in connexion with the zinc, forms a galvanic battery of many thousands, or rather millions, of pairs of plates, the impurities being protected, and the zinc destroyed.

It has no doubt surprised many who have made use of zinc, to find it in a few weeks or months, according to circumstances, perforated with small holes, and completely destroyed. We say according to circumstances, because the ordinary *time* zinc lasts depends not only on the amount of impurities ontained in it, but also on the exciting fluid to

which it is subjected. Exposed to the action of water from the atmosphere, the destructive influence operates comparatively slowly; but with more exciting fluids very rapidly.

Thus, a roof erected in the neighbourhood of a vinegar distillery, was completely destroyed in six weeks; and vessels used for dairy purposes have lasted but a very short time, owing to the presence of acids—these causing a rapid galvanic action between the zinc and its impurities. It is then quite evident that impure zinc, being itself valueless, cannot afford protection to any other metal. Now, the only process yet in use for the purpose of coating iron with zinc, is that of immersing the iron in melted zinc. This we conceive open to many objections. The iron by this process being raised to a temperature of at least 800°, causes it to combine with the zinc, forming an alloy on the surface, which changes its state, and becomes brittle. But upon this subject, we shall refer to the report made by M. Dumas to the French Academy. He says—

"The zincing of iron, made by steeping iron in a bath of melted zinc, has many inconveniences; besides, the iron combining with the zinc, constitutes a very brittle, superficial alloy. The iron loses its tenacity—a circumstance which is not perceived.

however, except in trying to zinc fine iron wire, or very thin plate. Besides, the surface, being covered with a layer of not very fusible metal, is always ill-formed. Thus, fine iron wire cannot be zinced by this process, as it becomes fragile and deformed; bullets cannot be zinced, as they become misshapen, and no longer of the same calibre."

We have reason to believe that very nice manipulations, and annealing the iron after zincing, may remove some of M. Dumas' objections to this process. Still, two fatal objections, in our opinion, would exist to its use: first, the impossibility of obtaining *pure* zinc, except at an enormous expense, the only process being sublimation or distillation; and secondly, the impossibility of retaining its purity, during the process of applying it to iron.

Setting aside the fact of an alloy of iron and zinc being produced by the action of heated iron immersed in melted zinc, the presence of foreign matter necessary to retain the zinc in fusion, renders it impure; these matters forming less fusible compounds, and zinc being very volatile, a great amount of waste is created.

But it is well known to all those acquainted with the deposition of metals from soluble salts by the electro process, that pure metal only is deposited;

so that this process is not open to the objection upon this head, which may be made to every other, more especially in treating a metal of so intractable a character as zinc. It is also applicable to all sizes and shapes of work, requires no expensive erections, and, what is important in large operations, may be performed anywhere, and by any person.

Although the protecting influence of zinc (we of course speak of pure zinc) upon other metals is practically unknown, it has been well known to men of science; and we shall take the liberty of quoting the opinions of some of the best chemists upon the subject; bearing in mind that zinc is electrically positive to other metals, and as such protects them from oxidation at a very trifling loss to itself—and that, by a well known law of electrical science, one body being electrically excited, that body induces its opposite state in other bodies with which it is in contact. Keeping these three points in view, we would call attention to the following opinions:—Dr. Kane says, "Zinc preserves the other metals, even if it be iron, from oxidation;" and, again, "Zinc, when exposed to the air even in presence of water, becomes covered with a varnish of a gray substance, probably a definite sub-oxide, which is not further

altered by exposure." Professor Graham, alluding to iron in water, says, "Articles of iron may be completely defended from the injury occasioned in this way, by the more positive metal zinc, while the protecting metal itself washes away slowly;" and further, when speaking of zinc, "When exposed to air, or placed in water, its surface becomes covered with a gray film of sub-oxide, which does not increase; and this film is better calculated to resist both the mechanical and chemical effects of other bodies than the metal itself, and preserves it." And Professor Daniel, in his new work, says, "That a plate of pure zinc, when immersed in water, speedily becomes dulled by the formation of a thin coat of oxide; but the oxidation proceeds no further, because the adhesion of the metal prevents a renewed contact of the metal and the water."

From these authorities we notice that pure zinc has a double protecting influence, the iron being protected by the zinc, and the zinc by its own oxide, besides that peculiar galvanic influence induced by the positive state of the zinc with respect to the iron. With regard to the peculiar adaptation of the electro processes to the zincing of iron, we shall again quote from M. Dumas' Report. He says, 'Manufacturers, and those concerned in military

affairs and the fine arts, will learn with interest that these processes enable us to zinc, in an economical manner, iron, steel, and cast iron, by means of the pile or battery, with the solution of zinc, by operating without heat, and consequently not interfering with the tenacity of the metal; by applying it in thin layers, and by thus preserving the general forms of the pieces, and even the appearance of their minutest details. The thinnest plate may receive this preparation without becoming brittle, and may be turned to account in roofing buildings."

We hope these authorities fully support what we have asserted, that pure zinc affords a perfect protection to iron, is not itself susceptible of rapid decay, and is easily applicable to the electro process. We are aware that other opinions upon this subject have been given; some have almost denied its galvanic influence, and have reduced it to what they term a *mere* "*tendency*," whilst others have much overstated it. Effects which may be witnessed every day, prove that there is a secret galvanic agency at work when metals are in contact. Take, for instance, the decay of iron when in contact with lead. Every one has observed that iron railings let into stone work with lead, are much decayed within a

short space of the contact of these two metals, while the remaining portion is comparatively sound. This effect is from the iron being positive to the lead, which is therefore protected at the expense of the iron.

It is matter of regret that zinc cannot be used with the same protecting property to articles in use at sea. This arises from its strong affinity for muriatic acid, thereby forming muriate of zinc, which being readily soluble is taken off by the water, leaving a new surface of zinc to be acted on, thus rapidly destroying the zinc.

In situations where the articles are not exposed to the run of salt water, the zinc will be found a protection.

The zinced iron solders readily. All other metals may be treated by this process for ornamental purposes. Copper will be found very useful. The depositions by alkaline solutions are perfectly firm, and not subject to the objection to which those made by acid solutions are; these being always insecure from the formation of an oxide upon the iron, induced by the acid of the solution. The deposited copper may be bronzed or gilt, and will be found most useful for ornamental work.

Many specimens of zinced iron, some of which had been exposed to the action of the weather for months, were exhibited to the meeting, as well as specimens of iron coated with copper by the same process.

While iron may be protected by an electro-deposit of zinc, the process, even when working with small articles, is connected with certain difficulties, and is at present but little appllied in practice, zincking by immersion, or as it is technically called "galvanizing," being preferred. In order that the metal to be galvanized will take a proper coating of zinc, it requires to be freed from oxide and impurities of every description, which is generally effected by pickling it in a liquid consisting of commercial sulphuric acid diluted with 10 to 12 parts of water and subsequent washing with clean water. The metal is then immersed in commercial hydrochloric acid and finally dried in an oven, when it is ready for the zinc bath. The temperature of the latter is a matter of vital importance to the quality of the work, and it is here that the skill and experience of the workman tells strongly. For sheet-iron work the heat of the bath is kept at about 1000° F.

WATER IN PIPES.

THIS table shows the quantity and weight of water contained in one fathom of length of pipes of different bores from 1 inch to 12 inches in diameter, advancing by ½ inch. The weight of a cubic foot of water is taken at 1000 ounces avoirdupois, and the imperial gallon at 10 lbs.

Diameter in inches.	Quantity in Cubic inches.	Quantity in Imperial gallons.	Weight in lb Avoird.
½	14.14	0.051	0.51
1	56.55	0.205	2.05
1½	127.23	0.460	4.60
2	226.19	0.818	8.18
2½	353.43	1.278	12.78
3	508.94	1.841	18.41
3½	692.72	2.506	25.06
4	904.78	3.272	32.72
4½	1145.11	4.142	41.42
5	1413.72	5.113	51.13
5½	1710.60	6.187	61.87
6	2035.75	7.363	73.63
6½	2389.18	8.641	86.41
7	2770.88	10.022	100.22
7½	3180.86	11.505	115.05
8	3619.11	13.090	130.90
8½	4085.64	14.777	147.77
9	4580.44	16.567	165.67
9½	5103.52	18.459	184.59
10	5654.87	20.453	204.53
10½	6234.49	22.550	225.50
11	6842.39	24.748	247.48
11½	7478.56	27.049	270.49
12	8143.01	29.452	294.52

ON CRUCIBLES.

THE manufacture of crucibles is a branch of the potter's art, requiring great care to insure success; and until lately, was at the best a very uncertain process. The chief requisites in a good crucible are, refractoriness in the strongest heats, capability of withstanding the corrosive effects of any substances that may be ignited in them, and the effects of sudden alterations of temperature. They must also be composed of a material sufficiently solid in its texture to prevent the passage of the solid metal through its pores.

The composition producing pots of the best quality is formed by pure fire clay mixed with finely ground *cement* of old crucibles, to which is added a portion of black lead or plumbago. The clay is prepared in the same manner as observed in pottery generally. The vessels, after being worked to the proper conical shape, are slowly dried, and then baked in a kiln.

The composition used in the Royal Foundry of Berlin is formed of eight parts in bulk of Stourbridge clay and cement, five of coke, and four of

graphite or plumbago. Crucibles manufactured from this mixture are capable of withstanding the greatest possible heat in which wrought iron melts, being equal to from 150° to 155° Wedgewood. They also bear sudden cooling without cracking. In the Berlin foundry they have been employed for twenty-three consecutive meltings of seventy-six pounds of iron each, which perhaps is the most complete and trying test that could be adopted.

Another composition is as follows:—8 pounds Stourbridge clay, 4 pounds burned clay cement, 2 pounds coke powder, and 2 pounds pipe clay; the whole being compressed in moulds while in a pasty state.

The Hessian crucibles from Great Almerode and Epterode, resist the action of fluxes, and are tolerably lasting. They are made from a fire clay containing a small amount of iron, but no lime. This is incorporated with silicious sand. These crucibles are rather porous, but they resist the effect of saline and leaden fluxes, and are not liable to crack, but they melt below the fusing point of bar iron.

The black lead crucibles bear a much higher heat. Their composition is two parts of graphite and one of fire clay; this is mixed into a pasty mass by means of water. The crucibles are baked slightly

short, if it be treated as steel often is—and be left in a furnace over night, it will be found, when cold, to have a perfect amorphous structure, every trace of chill-crystals will be gone, and the whole piece will be non-crystalline gray cast-iron. If this is the effect upon coarse cast-iron, what better is to be expected from fine cast-steel?

A piece of fine tap-steel after having been in a furnace over night will act as follows:

It will be harsh in the lathe and spoil the cutting tools.

When hardened it will almost certainly crack; if it does not crack, it will have been a remarkably good steel to begin with. When the temper is drawn to the proper color and the tap is put into use, the teeth will either crumble off or crush down like so much lead.

Upon breaking the tap the grain will be coarse and the steel brittle. To anneal any piece of steel, heat it red hot; heat it *uniformly* and heat it *through*, taking care not to let the ends and corners get too hot.

As soon as it is hot take it out of the fire, the sooner the better, and cool it as slowly as possible. A good rule for heating is to heat it at so low a red that when the piece is cold it will show the blue

gloss of the oxide that was put there by the hammer or the rolls.

Steel annealed in this way will cut very soft; it will harden very hard without cracking, and when tempered it will be very strong, nicely refined, and will hold a keen, strong edge.

HARDENING STEEL.

THE process of hardening steel is called *tempering* or *attempering*, and consists in that novel arrangement of the particles which is produced when steel, while hot, is plunged into cold liquids, as water. The colder the liquid, or the more sudden the operation of cooling, the harder will the steel be.

Case-hardening is the superficial conversion of the surface of iron into steel, by heating it in contact with animal carbon, in close vessels. Bar iron is converted into steel in the same way, only that powdered charcoal is the substance in which it is imbedded.

ON BORON.

THIS is the basis of a substance which has been long and extensively used in the arts and in medicine, under the name of *borax*. It is found abundantly in Thibet and in *South America*, but in a

state too impure to be used without refining. This was long a secret process practised by the Venetians and Dutch, who imported the crude salt into Europe, under the name of *tincal.*

Borax has a sweetish taste, and is "soluble in twelve parts of cold, and two parts of boiling water." Its crystals are transparent, but effloresce and become opaque in a dry atmosphere; and they appear luminous by friction in the dark.

It melts at a heat a little above that of boiling water, and gives out its water of crystallization, after which it forms a spongy mass, well known as calcined borax. When further heated to ignition, it passes into a glassy-looking substance, known as glacial borax.

Boracic acid is obtained in unlimited quantity from the lakes of Tuscany. The water requires simply to be evaporated until the acid solution has been sufficiently concentrated to afford crystals. The acid thus obtained is chiefly taken to M. Payen's works, at Marseilles, where it is manufactured into borax.

Dry borax, at a high temperature, has the remarkable property of melting and vitrifying the metallic oxides into glasses of different colours. On this account it is a most useful reagent for the blow

pipe. With oxide of chrome it forms an emerald green glass, and with oxide of cobalt an intensely blue glass.

Oxide of copper tinges it pale-blue; oxides of iron, bottle-green; oxide of tin, opal; oxide of manganese, violet; oxide of nickel, pale yellowish-green. With the oxides of silver and zinc, and with several of the earths, it forms white enamels.

Borax, in consequence of this property of vitrifying the metallic oxides, is used to clean the surface of metals, in processes of soldering with hard solder, and of welding *cast steel.*

It is also valuable in the fusion of metals to protect their surface from oxidizement. And it is worthy of remark, that, when mixed with shell-lac, in the proportion of one part to five, borax renders that resinous substance soluble in water, and forms with it a species of varnish.

ON SULPHUR.

THIS element, popularly known as *brimstone*, stands sufficiently well characterized by its brittleness, non-metallic appearance, and peculiar yellow colour. As a combustible it is universally known. Exposed to a temperature of 218° it melts almost into a liquid. When heated a few degrees higher, it becomes tenacious; and when heated to the temperature of 300°, it takes fire, burns away with a lambent blue flame, and leaves no residuum. As the temperature rises the flame becomes more white: and in pure oxygen gas the combustion goes on with great brilliancy.

If, while melted and viscid, sulphur be poured into cold water, it acquires somewhat the consistency of soft sealing-wax, and in this state it is very commonly used for taking impressions from seals and medals.

Native sulphur is brought into this country chiefly from Sicily, where it occurs in beds of a blue clay formation, occupying the central half of the south coast of the island, and extending inwards as far as the district of Etna. Sulphur is also an abundant ingredient in various minerals: iron pyrites and

galena, sulphurets of iron and lead, are particularly abundant in some localities; and at one time a large portion of the sulphur used in England was obtained from the copper pyrites of the mines of Anglesey. It was, however, less pure than the fine sulphur of Sicily, and other volcanic districts, being commonly mixed with arsenic and other metallic impregnations, which are difficult to separate.

Sulphur is sometimes employed for cementing iron bars into stone; and at present it is in repute for taking impressions of seals and cameos. When used for this purpose, it is commonly kept previously melted for some time, to give the casts the appearance of bronze. The principal consumption of it, however, is in the manufacture of sulphuric acid, gunpowder, and vermillion.

When the end of a sulphur match is lighted, the flame emits copious fumes, which are a compound of oxygen and sulphur. These fumes are intensely acid to the taste; they constitute what is called sulphurous acid, the first of the combinations of sulphur and oxygen. The gas has a strong affinity for the water, and the solution which it forms with it is known as liquid sulphurous acid. This, if left exposed to the air, absorbs more oxygen, and passes into sulphuric acid.

Sulphur also combines with hydrogen, forming the highly poisonous and offensive gas known as sulphuretted hydrogen, and which not unfrequently contaminates the coal gas supplied to us for illumination. Sulphur and carbon also combine, and form a beautifully transparent and colourless liquid, exceedingly volatile, and giving off an odour the most fœtid and nauseous which it is possible to conceive. Sulphur likewise enters into combination with metals, forming sulphurets, and is a most excellent flux in the making of brazing solder.

SELENIUM.

THIS is a rare elementary substance, nearly allied to sulphur in its properties, although it in some respects partakes of the nature of a metal. It was discovered by Berzelius, in 1817, in the refuse of an oil of vitriol manufactory, where it was derived from the iron pyrites employed in the works, and which contain a mixture in very minute proportions of a similar compound of selenium and iron. It has also been found sparingly in combination with seve

ral other metals, as lead, cobalt, copper, and bismuth; and with sulphur, in the volcanic products of the Lipari Islands.

It is separated from its combinations with difficulty, and hitherto only in minute quantities. When obtained free of admixture, selenium, at common temperatures, is brittle, solid, of a reddish-brown colour, and metallic lustre, without taste or smell. But when finely powdered the powder assumes a deep-red, inclined to purple. It softens at the temperature of 180°; is pasty at 200°, and melts at a few degrees above the boiling point of water. When warm it exhales a strong odour of decayed horse-radish, and is so ductile that it may be drawn into threads, which are red by transmitted, but gray by reflected light. It boils at 600°, and in close vessels throws off deep-yellow vapours, which condense into black, metallic-looking drops.

ON CHLORINE.

CHLORINE enters into numerous highly important and interesting combinations. Various bodies, when immersed in it when in a liquid state (that is, when,

submitted to a pressure of four atmospheres, it becomes a yellow transparent liquid), take fire spontaneously. A candle burns in it with a red flame, and a piece of phosphorus introduced into it, burns with a pale-white light. Copper, tin, zinc, antimony, and arsenic, when introduced into it in their leaves, or reduced to filings, take fire, and, combining with the gas, form compounds analogous to the oxides, and which are therefore called *chlorides*. Mercury also enters rapidly into combination with it, forming chloride of mercury, a substance better known as *corrosive sublimate*.

The grand source of chlorine is the water of the ocean. This is an enormous solution of *salt*—a universally known and indispensable article of consumption with the human race; an article, indeed, which seems to be essentially necessary to maintain the body in a healthy condition. Now this *salt* is a compound of chlorine and a metal. It is, in fact, a chloride, consisting, when pure, of 60 of chlorine, and 40 of sodium, in 100 parts; and whether it be obtained by evaporation of sea water, or be dug out of the salt mines of Wieliczka or Northwich, it has the same composition.

SOME of the minerals contain but one earth; but minerals are found in which the earths are combined in different proportions, by processes which produce that apparently endless variety of objects which mineral nature presents for our contemplation.

Science has of late years demonstrated that none of the earths are simple substances, that is, chemical elements. Sir Humphrey Davy has proved that none of them are entitled to that character, that they are in fact compounds of certain metals with oxygen—that is, metallic oxides. This has been shown by the very direct method of abstracting oxygen from them, and thereby separating the metallic base. Thus, alumina (being the basis of alum) is the oxide of a gray and hard metal like platinum, and which burns with great brilliancy when heated with access of air, and reproduces the earth by absorption of oxygen from the atmosphere.

It is very singular that soda, as distinguished from potash, has been known with us only of late years; whereas it was familiar to the Greeks and Hebrews. It was also known in Egypt, where it is found native, and is known by the name of *natron*—which

occurs in the Bible. Thus Jeremiah speaks of washing in natron.*

From the preceding summary we may reckon ourselves justified in concluding that the solid strata of our globe—that is, the superficial shell with which we are acquainted, if not the vast mass of the globe itself—are nothing more than masses of metals of different kinds, disguised by oxygen: that they are in fact oxides, and bear evidence, in many cases, of being the products of combustion.

ANILINE BRONZING FLUID.

TAKE 10 parts of aniline red and 5 parts of aniline purple and dissolve in 100 parts of alcohol at 95°, taking care to assist the solution by placing the vessel in a sand or water bath. As soon as the solution is effected, 5 parts of benzoic acid are added and the whole is boiled from 5 to 10 minutes until the greenish color of the mixture is transformed into a fine light-colored bronze. This bronze is said to be very brilliant, and to be applicable to all metals, as well as to other substances. It is easily laid on with a brush and dries promptly.

BRONZE BARBÉDIENNE ON BRASS.

Freshly precipitated arsenious sulphide is dissolved

* Jeremiah ii. 22.

in ammonia, and antimonious sulphide is added until a dark yellow color is produced. Heat the solution carefully to about 95° F. Leave the articles in the bath until they have acquired a dark brown color, and develop the color by scratch-brushing.

Steel-gray coating on Brass.

Antimony sulphide and fine iron filings, 1 part of each; hydrochloric acid 3 parts; and water 3 or 4 parts.

TO BROWN GUN BARRELS.

TAKE of nitric acid, half an ounce; sweet spirit of nitre half an ounce; blue vitriol, two ounces; tincture of steel, one ounce. Mix all together in eight gills of water. Apply this mixture with a sponge, then heat the barrel a little, and move the *oxide* with a hard brush. This operation may be repeated a third and fourth time, till you have the brown required.

It is then to be carefully wiped, and sponged with boiling water, in which there has been put a small quantity of potass. The barrel being taken from the water, must be made perfectly dry, and then rubbed smooth with a burnisher of hard wood; afterwards heated to the height of boiling water and varnished with the following varnish:—

Varnish for gun barrels that have undergone the process of browning.

TAKE of spirits of wine two parts, dragon's blood, powdered, three drachms; shell-lac bruised, one ounce: dissolve all together. This varnish being laid on the barrel, and become perfectly dry, must be rubbed with a burnisher to render it smooth and glossy.

ETHEREAL SOLUTION OF GOLD.

SATURATE nitro-hydrochloric acid with pure gold. Crystallize, and with the crystals saturate water. Shake this aqueous solution in a phial with an equal volume of pure ether; then two fluids will result, the lighter of which is the ethereal solution of gold, and may easily be separated. This must be kept in a darkened bottle, as by exposure to light it quickly decomposes, flakes of gold being deposited.

Any substance moistened with this will receive a coating of metallic gold, and hence metals may be rendered not liable to corrosion.

Even in the dark it cannot be preserved long, but undergoes slow decomposition

TO COAT SMALL NAILS, ETC., WITH TIN.

PUT half an ounce of powdered tin (which may be procured of any operative chemist), into a common Florence flask, pour on about two ounces of concentrated muriatic acid, and boil over a spirit lamp until the tin is dissolved. When cool, pour into any convenient vessel and dilute with about an equal bulk of pure water. Drop in the nails required to be coated, holding the vessel so that they may all fall to one side. Immerse a piece of sheet-copper into the solution, as far apart from the nails as possible, and connect it with the latter by means of a piece of copper wire. The effect of this arrangement is the development of a current of voltaic electricity, which causes a rapid decomposition of the fluid, and the deposition of tin on the surface of the nails. After being subjected to this treatment for about an hour, the nails will be found to have received a thick coating of metal, and may then be removed from the liquid, dried, and polished.

Recourse is frequently had to the above process for the purpose of coating the nibs of steel pens with tin, in order to prevent them from rusting. It succeeds better than any other method ever tried.

BRONZING ELECTROTYPE CASTS.

Chemical Bronze.

THERE are many modes of bronzing employed in the arts; the intent of each is to bring out the workmanship of the object. The selection is entirely a matter of taste. To prevent too great a sameness of appearance in a cabinet, it is, perhaps, better not to confine oneself to a solitary method.

A chemical bronze may be made by boiling two ounces of carbonate of ammonia with one ounce of acetate of copper, in half a pint of vinegar, till the vinegar is nearly evaporated. Into this, pour a solution consisting of sixty-two grains of muriate of ammonia, and fifteen grains and a half of oxalic acid, in half a pint of vinegar. Replace the vessel on the fire till the contents boil; when cold, strain through filtering paper; preserve the liquor for use. The remaining sediment may be again treated with another half pint of the solution. This preparation must only be applied to medals bright and clean.

Dirty specimens may be polished by an article used in domestic economy, consisting of rottenstone, soft soap, and water. The medal is to be

well rubbed with a hard brush dipped in this. Care must be taken not to scratch the medal. It must afterwards be washed in water and placed to dry; when dry, the application of the leather and plate-brush will produce the required polish. Medals may also be cleansed by dipping them in *nitric acid*, either concentrated or diluted. Wax and grease may be removed by boiling in *pearl-ash* and water, or by pouring the boiling ley on the medals.

In applying the bronze, first warm the medal, then dip a camel-hair pencil into the liquor and brush the surface for half a minute; immediately after, pour boiling water over it. Directly the medal is dry, rub its surface lightly with soft cotton very slightly moistened in linseed oil. Gentle friction with a piece of dry cotton will finish the operation. The colour produced by this means is *red;* its tints vary according to circumstances. Medals bronzed thus must be examined occasionally before they are consigned to the *cabinet;* for if perchance the vinegar has not been perfectly washed away, they will be disfigured by the formation of a green powder,—the acetate of copper. Should this occur, it may be removed by means of the moist and dry cotton.

with a piece of sal-ammoniac placed between two wires, likewise some powder sprinkled upon it, to keep the metal from oxidating. Apply the tin, wipe it over with a piece of tow, then the work is finished.

LIQUID GLUE.

SHELL-LAC dissolved in wood naptha (the pyroxilic spirit of the chemists, and the naptha of the oil and colour shops) makes good liquid glue, water-proof, and not requiring the application of heat. A quarter of a pound avoirdupois of shell-lac to be dissolved in three ounces of naptha, apothecaries' measure. Put the former into a wide-mouthed bottle; pour the latter upon it, and stir the mixture two or three times during the first thirty-six hours.

ARTIFICIAL FIRE-CLAY.

THE fusibility of common clay arises from the presence of impurities, such as lime, iron, and magnesia. These substances may be easily removed by steeping

in hot muriatic acid, then washing with water, and drying. Excellent crucibles may be made from common clay prepared in this manner.

A CEMENT WHICH RESISTS THE ACTION OF FIRE AND WATER.

TAKE half a pint of milk, mix with it an equal quantity of vinegar, so as to coagulate the milk; separate the curds from the whey, and mix the latter with the whites of four or five eggs, well beaten up. The mixture of these two substances being complete, add to them quick-lime, which has been passed through a sieve; make the whole into a thick paste, to be of the consistence of *putty* when used.

This cement has been applied to close the fissure of an iron cauldron for the boiling of pitch, and which has been in use for five years without requiring further repairs.

CEMENT FOR THE JOINTS OF CAST IRON.

TAKE of cast iron borings, 20 pounds; flour of sulphur, 2 ounces; muriate of ammonia, 1 ounce; mix intimately in the dry state, and then add a sufficient quantity of warm water to render the whole quite wet. Press the mass together in a lump, and allow it to remain until such time as the combined action of the materials renders it quite hot, in which state it must be hammered, with proper tools, into the joints.

NIELLO-METALLIC ORNAMENTS.

COVER the object to be ornamented with an etching ground similar to that employed by copper-plate engravers; draw the ornament with a needle, and etch it by means of a corrosive acid; then carefully remove the etching ground with the proper dissolving fluids (such as oil of turpentine, ether, &c.), and afterwards wash the object quite clean, and set for

a moment with a weak acid. Place it now in a galvano-plastic apparatus, and leave it until it becomes galvano-plastically covered, that is, all the etched lines filled up. When all the lines and cavities are completely filled up in this way, and the deposit in them is equally high as, or yet higher than, the plain surface, the object must be taken out of the galvano-plastic apparatus, and the metallic layer, which has been raised by the operation, ground or planed off until brought to the same level with the metal of the object, leaving the etched lines or cavities full.

Of course, the metal of the object to be ornamented and the metallic deposit must be different. The effect produced is extremely pretty, and the means cheap and simple.

TRACING PAPER.

Mix six parts (by weight) of spirits of turpentine, one of resin, one of boiled nut oil, and lay on with either a brush or sponge.

TO FIX DRAWINGS.

A METHOD which is equally simple and ingenious, of giving to drawings in pencils and crayons the fixidity of painting, and without injury, is obtained by spreading over the back of the paper an alcoholic solution of white gum-lac. This solution quickly penetrates the paper, and enters even into the marks of the crayon on the other side.

The alcohol rapidly evaporates, so that in an instant all the light dust from the crayons and chalk, which resembles that on the wings of a butterfly, adheres so firmly to the paper, that the drawing may be rubbed and carried about without the least particle being effaced.

The following are the accurate proportions of the solution: 10 parts of common gum-lac are dissolved in 120 parts of alcohol; the liquid is afterwards bleached with animal charcoal.

For the same purpose may be used even the ready-made paint that can be purchased at the colour stores, containing a sixth of white-lac, and adding two-thirds of rectified spirits of wine. After it has been filtered, there is nothing further to be done

than to spread a layer of either of these solutions at the back of the drawing, in order to give them the solidity required.

ANTIDOTE TO ARSENIC

MAGNESIA is an antidote to arsenic, equally efficacious with peroxide of iron, and preferable to it, inasmuch as it is completely innocuous in almost any quantity, and can be procured in any form.

TO SOFTEN IVORY.

SLICE half a pound of mandrake and put it into a quart of the best vinegar, into which immerse your ivory. Let it stand in a warm place for 48 hours, and you will then be enabled to bend the ivory into any required form.

TO SEPARATE THE METALLIC PORTION FROM GOLD AND SILVER LACE.

IMMERSE the lace for a short time in nitric acid.

BLUEING AND GILDING STEEL.

THE mode employed in blueing steel is merely tc subject it to heat. The dark blue is produced at a temperature of 600°, the full blue at 500°, and the blue at 550°.

Steel may be gilded by the following process: to a solution of the muriale of gold, add nearly as much sulphuric ether. The ether reduces the gold to a metallic state and keeps it in solution, while the muriatic acid separates, deprived of its gold, and forms a distinct fluid. Put the steel to be gilded into the ether, which speedily evaporates, depositing a coat of gold on the metal by dint of the attraction between them. After the steel has been immersed it should be dipped into cold water, and the burnisher should be applied, which strengthens its adhesion. Figures, flowers, and all descriptions of ornaments and devices, may be drawn on the steel by using the ether with a fine camel-hair pencil, or writing pen.

TO HARDEN STEEL DIES.

A VESSEL holding 200 gallons of water, is to be placed at the height of 40 feet above the room in which the dies are to be hardened. From this vessel the water is conducted through a pipe of one inch and a quarter in diameter, with a cock at the bottom, and nozzles of different sizes to regulate the diameter of the jet of water. Under one of these place the heated dies, the water being directed on to the centre of the upper surface. By this process the die is hardened in a way as best to sustain the pressure to which it is to be subjected; and the middle of the face, which by the old process was apt to remain soft, now becomes the hardest part. The hardened part of the dies so managed, were it to be separated, would be found to be in the segment of a sphere, resting in the lower softer part, as in a dish, the hardness, of course, gradually decreasing as you descend towards the foot. Dies thus hardened, preserve their form till fairly worn out.

PORTABLE GLUE.

BOIL one pound of the best Russian glue, and strain. Then add half a pound of brown sugar, and boil thick. When cold, the compound may be poured into small moulds, and afterwards cut into pieces.

This glue is very soluble in warm water, and is particularly useful to artists for fixing their drawing-paper to the board.

PREVENTION OF CORROSION.

THE best means of preventing corrosion of metals is to dip the articles first into a very dilute *nitric acid*, to immerse them afterwards in linseed oil, and to allow the excess of oil to drain off. By this process metals are effectually prevented from rust or oxidation.

CEMENT.

MIX ground white lead with as much finely-powdered red lead as will make it of the consistence of soft putty.

SOLUBLE GLASS.

WHAT is called soluble glass is now beginning to come into use as a covering for wood and other practical purposes. It is composed of 15 parts of powdered quartz, 10 parts of potash, and 1 part of charcoal.

These are melted together, worked in cold water, and then boiled with 5 parts of water, in which it entirely dissolves. It is then applied to wood-work, or any other required substance. As it cools it gelatinises, and dries up into a transparent, colourless glass, on any surface to which it has been applied. It renders wood nearly incombustible

JAPANNING.

First. Provide yourself with a small muller and stone, to grind any colour that you may require.

Secondly. Prepare yourself with white hard varnish, brown varnish, turpentine varnish, Japan gold size, and spirit of turpentine, which you may keep in separate bottles until required.

Thirdly. Provide yourself with flake white, red lead, vermillion, lake, Prussian blue, king's and patent yellow, orpiment, spruce and brown ochre, mineral green, verditer, burnt umber, and lamp-black.

Observe that all wood-work must be prepared with size, and some coarser material mixed with it, in order to fill up and harden the grain of the wood —such, indeed, as may best suit the colour intended to be laid on—which must be rubbed smooth with glass-paper when dry; but in case of accident it is seldom necessary to resize the damaged places unless they are considerable.

With the foregoing colours you may match always any one in use for japanning, always observing to grind your colours smooth in spirit of turpentine;

add a small quantity of turpentine and spirit varnish, and lay it carefully on with a camel's-hair brush, then varnish with brown or white spirit varnish, according to colour.

For a black, mix up a little size and lamp-black, and it will bear a good gloss without varnishing over. To imitate black rosewood, a black ground must be given to the wood, after which take some finely levigated red lead, mixed up as before directed, and lay on with a flat, stiff brush, in imitation of the streaks in the wood; after which take a small quantity of lake, ground fine, and mix it with brown spirit varnish, carefully observing not to have more colour in it than will just tinge the varnish; but should it happen on trial to be still too red, you may easily assist it with a little umber, ground very fine, with which pass over the whole of the work intended to imitate black rosewood, and it will have the desired effect. If the work be done by a good japanner, according to the foregoing rules, it will, when varnished and polished, scarcely be distinguished from the real wood.

TO PRESERVE POLISHED STEEL FROM RUST.

MIX some oil with caoutchouc; melt in a close vessel, stirring to prevent burning. A high temperature will be required. This will form a perfect air-proof skin over the surface, which may very easily be removed by brushing with warm oil of turpentine.

CEMENT FOR ATTACHING METAL TO GLASS.

TAKE two ounces of a thick solution of glue, and mix with one ounce of linseed oil varnish, or three-quarters of an ounce of Venice turpentine. Boil together, agitating until the mixture becomes as intimate as possible. The pieces cemented should be fastened together for the space of forty-eight or sixty hours.

VARNISH FOR COLOURED DRAWINGS.

CANADA balsam, one ounce; oil of turpentine, [illegible] ounces. Dissolve. Size the drawings first with a jelly of isinglass, and when dry apply the varnish, which will make them look like oil paintings.

JAPANNERS' COPAL VARNISH.

TAKE of the best pale African copal, seven pounds; fuse; add two quarts of clarified linseed oil. Boil for a quarter of an hour, remove it into the open air, and add three gallons of boiling oil of turpentine. Mix well, then strain into the cistern, and cover up immediately.

SOFT VARNISH.

CALLOT'S soft varnish for etching:—linseed oil, four ounces; and half an ounce each of gum benzoin and white wax. Boil to two-thirds.

HARD VARNISH.

CALLOT'S hard varnish for etching:—Take four ounces each of linseed oil and mastic, and melt together.

FLEXIBLE VARNISH.

FLEXIBLE varnish for balloons, &c.:—India-rubber in shavings, one ounce; mineral naptha, two pounds. Digest at a gentle heat in a close vessel until dissolved, then strain.

FRENCH POLISH.

DISSOLVE one part of gum-mastic, and one part of gum-sandarach, in forty parts of spirits of wine, and then add three parts of shell-lac. This process may be performed by putting the ingredients into a loosely corked bottle, and then placing it in a vessel

of water a little below 173° Fahrenheit, or the boiling point of spirits of wine, until the solution be effected.

BRUNSWICK BLACK.

FOREIGN asphaltum, forty-five pounds; drying oil, six gallons; and litharge, six pounds. Boil for two hours, then add dark gum amber (fused), eight pounds; hot linseed oil, two gallons. Boil for two hours longer, or until a little of the mass, when cooled, may be rolled into pills. Then withdraw the heat, and afterwards thin down with twenty-five gallons of oil of turpentine. Used for iron-work, &c

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MORDANT VARNISH.

TAKE one ounce of mastic, one ounce of sandarach, half an ounce of gum-gamboge, and a quarter of an ounce of turpentine. Dissolve in six ounces of spirits of turpentine.

ANOTHER.

PLACE a quantity of boiled oil in a pan, and subject it to a strong heat. When a disengagement of black smoke takes place, set it on fire, and in a few moments extinguish it, by covering over the pan. Then pour the matter while heated into a bottle, previously warmed, adding to it a little oll of turpentine.

ANOTHER.

MIX asphalte and drying oil, diluted with oil of turpentine. For bronzing, or very pale gilding.

ANOTHER.

TAKE a quantity of camphorated copal varnish, and add a little red lead.

ANOTHER.

DISSOLVE a little honey in thick glue. For gilding, &c.

SUPERIOR GREEN TRANSPARENT VARNISH.

THE beautiful, transparent green varnish employed to give a fine glittering colour to gilt or other decorated work, may be prepared as follows:

Grind a small quantity of Chinese blue with about double the quantity of finely powdered chromate of potash, and a sufficient quantity of copal varnish thinned with turpentine. The mixture requires the most elaborate grinding or incorporating, otherwise it will not be transparent, and therefore useless for the purpose to which it is intended. The "tone" of the colour may be varied by an alteration in the proportion of the ingredients. A preponderance of chromate of potash causes a yellowish shade in the green, as might have been expected; and *vice versa* with the blue, under the same circumstances. This coloured varnish will produce a very striking effect in japanned goods, paper-hangings, &c., and can be made at a very cheap rate.

ETCHING VARNISH.

TAKE of white wax, two ounces; and of black and Burgundy pitch, each half an ounce. Melt together, adding by degrees two ounces of powdered asphaltum. Then boil until a drop taken out on a plate will break when cold, by being bent double two or three times between the fingers, when it must be poured into warm water, and made into small balls for use.

COLORING BRASS A DEEP BLUE.

A COLD method of coloring brass a deep blue is as follows: 100 grammes of carbonate of copper and 750 grammes of ammonia are introduced in a decanter, well corked, and shaken until dissolution is effected. There are then added 150 cubic centimeters of distilled water. The mixture is shaken once more, shortly after which it is ready for use. The liquid should be kept in a cool place, in firmly closed bottles or in glass vessels, with a large opening, the edges of which have been subjected to emery friction and covered by plates of greased glass. When the liquid has lost its strength, it can be recuperated by the addition of a little ammonia. The articles to be colored should be perfectly clean; especial care should be taken to clear them of all trace of grease. They are then suspended by a brass wire in the liquid in which they are entirely immersed, and a to-and-fro movement is commuticated to them. After the expiration of two or three minutes they are taken from the bath, washed in clean water, and dried in sawdust. It is necessary that the operation be conducted with as little exposure to the air as possible. Handsome shades are only obtained in the case of

brass and tombac—that is to say, copper and zinc alloys. The bath cannot be utilized for coloring bronze (copper-tin), argentine, and other metallic alloys.

ON PATTERN-MAKING—CONTRACTION OF METALS, ETC.

IT is necessary to make patterns in some degree larger than the intended castings, to allow for their contraction in cooling, which equals from about the ninety-fifth to the ninety-eighth part of the length, or nearly one per cent. This allowance is very easily and correctly managed by the employment of a contraction-rule, which is made like a surveyor's rod, but one-eighth of an inch longer in every foot than ordinary standard measures. By the employment of such contraction-rules every measurement of the pattern is made proportionally larger without any trouble of calculation.

When a wood pattern is made, from which an iron pattern is to be made, the cast being intended to serve as the permanent foundry pattern, as there are two shrinkages to allow for, a *double* contraction-rule is employed, or one the length of which is one-quarter of an inch in excess in every foot. These rules are particularly important in setting

out alterations in, or additions to, existing machinery. The latter is measured with the common rule, and the new patterns are set out to the same nominal measures, with a single or double contraction-rule, as the case may be—the three being made in some respects dissimilar, to avoid confusion in their use. The entire neglect of contraction-rules incurs additional trouble and uncertainty. The contraction of brass is nearly three-sixteenths of an inch in every foot, but from the small size of brass castings the contraction-rule is less required for them, as the differences may be easily allowed for without it. Iron castings weigh about fourteen times as much as the ordinary deal and fir patterns from which they are made—that being nearly the ratio of the specific gravities of those materials.

In reference to the *qualities* of *Iron*, it may be worthy of remark, that the same mixture of iron will be found to differ very much according to the size of the objects in which it is cast. Iron which in a plate one-fourth of an inch thick may be quite brittle and hard, will mostly be of good, soft, and useful quality in a stout bar, or plate of two or three inches thick. Thick castings are necessarily slow in cooling, and are seldom very hard unless intentionally made so.

Between the extremes (say three parts of pig-iron to one of old, or three parts of old iron to one of pig-iron), various qualities may be selected. In castings for machinery, the general aim is to obtain a strong, sound, and tough iron. Mixtures of this nature which are used for iron ordnance, are called gun-metal amongst the gun-founders.

CONDUCTING HEAT OF BRASS AND IRON.

THE power of conducting heat is considerably less, in red-hot iron, than in copper and brass; and therefore the moulds for the latter require to be in a drier condition than those which may be used for iron But in either case, the presence of superfluous moisture is always attended with some danger to the individual, as well as to the work. Iron founders may use their moulds with safety when sensibly more moist than is admissible for brass and copper castings. It is confirmatory of the fact, that the more dense the *mould*, the drier it must be—as the sand used by iron-founders is also coarser, and therefore more porous than that employed by brass-founders.

VARIETIES OF TOMBAC.

	1	2	3	4	5	6	7	8	9	10
Copper...	82–0	82	82–3	80	85	85–3	86	90–0	92	97–8
Zinc.....	18–0	18	17–5	17	15	14–7	14	7–9	8	2–2
Lead	1–5	3	.....	.....	.....	.....	.....	1–6	.....	.....
Tin	3–0	1	0–2	3	trace	.....	.....	.....	.....	.....
	104–5	104	100–0	100	100	100–0	100	99–5	100	100–0

Nos. 1, 2, and 3, are for making gilt articles; 4, French mixture for sword-handles, &c.; 5, Okar metal near Goslar, in the Hartz; 6, Yellow tombac for Parisian gilt ornaments; 7, Hanoverian; 8, Chryso chalk; 9, Paris tombac; and 10 the red tombac of Vienna.

ON SAND-CORE MOULDING, BLACKENING, ETC.

AMONGST the great variety of work denominated green-sand moulding, much and varied contrivance is displayed in the structure of the moulds. In particular, the management of cores is a matter of very considerable importance, and the malformation of them is a prolific source of failure in the production of sound castings.

Cores are especially useful for forming vacancies in castings. Their forms may be long, and proportionably small in diameter or winding, and

otherwise intricate; and seeing that they are necessarily surrounded by the metal when cast, they ought to have, as much as may be, the qualities of firmness of substance and openness of pores. Cores are commonly composed of rock-sand and sea-sand. The former having a proportion of clay in its composition, to which it owes its powerful cohesiveness when dried, serves very well for short cores that rest on the green sand at both ends, as open communication with it is thus afforded for the free escape of the air in the interstices of the cores.

But when rock-sand is used for cores of a considerable length (which, of course, are surrounded on all sides by the metal, except the small imbedded portions at the extremities, by which alone the air can escape), it requires to be moderated by the admixture of free-sand, as a counteractant to the clay. The clay communicates the necessary cohesiveness to the material of the core; the sand, on the contrary, loose and open, renders it less binding and more porous. Free-sand alone is also employed in the construction of confined cores, that they may afterward be easily extracted, as the sand has naturally no power of cohesion.

Wanting cohesiveness, it must be tempered to a

proper consistency by the addition of clay and water, yeast, flour, or the refuse of pease-meal, used for light flat moulding purposes. In the use of the latter materials, it must be accurately proportioned to the sand with which it is mixed. The clay-water is, in ordinary cases, made use of as a cement, and the yeast only in very particular circumstances. For large compact masses of core the common green sand may be used.

The longer cores are stiffened by iron wires and small rods, which are bent, if necessary, to the form of the cores. These rods are dipped in clay-wash, and enveloped in the core in the progress of its formation, and are afterward extracted from the casting. The cores of considerable length are pierced longitudinally by wires for the "escape of the air;" or in cases where this is impracticable, on account of bends or angles in the core, a piece of string is laid in the sand alongside the stiffening wires, which is afterward drawn out, when the core is dry, leaving its perforation behind it. With all these precautions, securing the strength of the cores and letting off the air, your castings have every chance of being good, and free from blow-holes When the bearings of cores at the extremities are considered unfi' for steadying them, they are fur-

ther sustained by staples struck into the sand at several places in their length, and projecting above it just as much as the thickness of metal, the core is placed upon them, and sustained steadily in its place. The staples are, of course, buried in the casting, and the projecting points outside cut off in the course of dressing it. Chaplets are used to bear up cores having plain surfaces. Another set of chaplets, or staples, are placed in the cope, and well secured at the back, when the flask is closed, firmly fixed, and in contact with the upper half of the core. It is thus prevented from floating off its seat when immersed in the fluid metal, and prevented from springing. This is a matter of greater moment than the mere sustaining of the core from below, as will be apparent on considering the great difference of specific gravities of sand, dry loam, and iron or brass.

In this case, the upward effective pressure of the fluid metal upon the core is proportional to the difference of their specific gravities, which, being so much in favor of metal, the pressure upward, sustained by the chaplets, cannot be much less than the weight of a body of metal of the same bulk as the core, for the support of which they are destined in brass-founding particularly, great care

should be taken that the staples and chaplets are sufficiently strong. Should they be too slightly made, they will bend or melt before the hot metal, and prove entirely useless. *This is too often neglected.*

Ordinary black-wash for cores consists of oak charcoal, powdered, and a little clay, diluted with horse-dung water. Blackening for moulds is often composed of finely ground plumbago, mixed with a little charcoal, the whole diluted with a solution of the soluble parts of horse-dung. This is frequently mixed with pease-meal, or other meal, glue, and extracts from the refuse of tanneries. But all these compositions are more or less too close, and cause a dull surface to the cast. The first is the best, if applied not too much diluted. Blackening, or a coating of carbon, will prevent the burning of the sand, and consequent roughness of the casting, as it fills the pores of the sand. A little plumbago mixed with it makes it more refractory still, and is very desirable where a great body of metal surrounds a small core.

One part of clay mixed with nine parts of free-sand, or any other pure sand, is considered sufficiently strong for core sands. Still, these properties depend very much on the nature of the sand and

the adhesiveness of the clay, and also what kind of cores are to be made from it—large and complicated cores being made stronger than small ones.

The various kinds of good moulding-sand employed in foundries for casting iron or brass, have been found to be of an almost uniform chemical composition, varying in grain or the aggregate form only. It contains between 93 and 96 parts silex, or grains of sand, and from 3 to 6 parts of clay, and a little oxide of iron in each 100 parts Moulding-sand which contains lime, magnesia, and other oxides of metal, is not applicable, particularly for the casting of iron or brass. Such sand is generally either too weak or too close—will not stand or retain its form, or it will cause the metal to boil through its closeness.

In practice, different kinds of castings require different kinds of sand for the purpose of moulding, which will furnish the subject for another article.

ON WASHING SWEEPINGS, ASHES, ETC., FROM BRASS FOUNDRY FURNACES—GILDERS' AND JEWELLERS' WORKSHOPS—AND PLACES WHERE METALLURGIC OPERATIONS ARE CARRIED ON.

THE clinkers, ashes, or cinders, which remain in furnaces after metallurgic operations have been completed, may appear to be among the most useless things. Not so, however. If they contain any metal, there are men who will ferret it out, by some means or other. Not many years since, the ashes of the coal or coke used in brass and bronze furnaces, were carried away, after picking, as rubbish. But shrewd people have detected a good deal of volatilized copper, &c., mixed up therewith, and the brass founder can now find a market for his ashes as an inferior kind of *ore;* or which is still more preferable, in case of slackness of work, can cleanse and smelt them himself; which every brass founder can (or at least, ought to know how to) do. It needs hardly to be stated, that all sorts of filings and raspings, cuttings and clippings, borings and turnings, and odds and ends in the metallic form, are all available for re-melting, whatsoever the metal may be; all is grist that comes to this mill.

If the metal be a cheap one, it will not pay to extricate a stray per centage from ashes and clinkers; but if it be one of the most costly metals, not only are all scraps and ashes and skimmings preserved, but particles are sought for in a way that may well astonish those to whom the subject is new.

Take gold as an example. There are dealers who sedulously wait upon gilders and jewellers, at intervals, to buy up every thing (be it what it may) which has gold in or upon it. Old and useless gilt frames are bought; they are burnt, and the ashes so treated as to yield up all their gold. The fragments and dust of gold, which arise during gilding, are bought and refined. The leather cushion which the gilder uses, is bought, when too old for use, for the sake of the gold particles which insinuate themselves into odd nooks and corners. The old leather apron of the jeweller is bought. It is a rich prize; for in spite of its dirty look, it possesses very auriferous attractions. The sweepings of the floor of a jeweller's workshop are bought, and there is probably no broom, the use of which is stipulated for with more strictness, than that with which such a floor is swept. In short, there are in this world, (and at no time so much as at present) a set of very useful people, who may be designated as manufac

turning scavengers. They clear away refuse, which would else encumber the ground, and they put money into the pockets both of buyers and sellers, they do effectually create a something, out of a commercial nothing. It is essentially necessary, however, for the brass founder (should he employ a smelter of metals to wash his foundry ashes, his own man being too busily engaged in the moulding shop) to have them cleansed and smelted on his own premises, as he will effect a considerable saving thereby, beside have a very superior metal, than if washed off the premises and returned after smelting. The reason is obvious: crucibles generally break before the tin, zinc, or lead is added to the copper, which is always melted first; this being the case, the smelter has an opportunity (and rarely fails to advantage by it) of reducing the alloy with the inferior metals, at the cost of the employer. There is great room for trickery here, and I have known brass founders themselves (and clever ones at that), who could not detect the imposition. Every brass founder ought to be capable of washing and smelting his own refuse and shop dirt. This may be done (as before stated) at any period of the year, and find him employment when he might otherwise have nothing to do in the moulding shop, as well

as save his employer from laying out cash for that which he has at home, if only gathered together.

CORNISH REFINING FLUX.

DEFLAGRATE, and afterward pulverize, two parts of *nitre*, and one part of *tartar*. The following fluxes answer the purpose very well, provided the *ores* be deprived of all their sulphur, or if they contain much earthy matter; because in the latter case they unite with them, and convert them into a thin glass, but if any quantity of sulphur remain, these fluxes unite with it, and form a *liver* of sulphur, which has the power of destroying a portion of all the metals; consequently, the assay must be, under such circumstances, very inaccurate. Limestone, feldspar, fluor-spar, quartz, sand-slate, and slugs, are all used as fluxes. Iron ores, on account of the argillaceous earth they contain, require calcareous additions; and the copper ores, rather slugs, or vitrescent stones, than calcareous earth.

CRUDE, OR WHITE FLUX.

ONE part nitre, to two parts tartar, mixed well together.

BLACK FLUX.

THE above flux detonates by means of kindled charcoal, and if the detonation be effected in a mortar slightly covered, the smoke that arises unites with the alkalized *nitre* and the tartar, and renders it *black*.

CORNISH REDUCING FLUX.

MIX well together, 10 ounces of tartar, 3 ounces and 6 drachms of nitre, and 3 ounces and 1 drachm of borax.

IMITATION SILVER METAL.

4½ pounds tin, ½ pound bismuth, ½ pound antimony, ½ pound lead. This metal retains its silvery brilliancy to the last.

ON CASE-HARDENING IRON.

CASE-HARDENING iron is done by reducing the prussiate of potash to a paste, in a little water smearing over your article, and heating it in the *fire to* a dull red heat, and then dip in cold water.

VARNISH FOR IRON.

THE best varnish for iron is red lead, laid on first with a very thin coat, left to dry, then give one or two more coats.

VARNISH FOR POLISHED IRON.

USE common gum copal varnish. You may mix a little oil in it.

TO PRESERVE GUM ARABIC SOLUTIONS.

A FEW drops of alcohol, or any essential oil, will preserve a quart of the mucilage of "*gum Arabic*" or "*gum Tragacanth*" from spoiling. A small quantity of dissolved *alum* will preserve flour paste.

BEST COMPOSITION OF BRASS FOR ROLLING AND FORGING.

ANY proportion between the extremes of 50 parts copper and 50 parts zinc, or 62 copper and

38 zinc, will roll and work at the red heat. The very best composition, however, is 60 parts copper to 40 parts zinc.

REMARKS ON THE FLUXING OF METALS.

METALS are contained in the ores, in most cases as compounds, and if it is the object to separate them, we are to put such matter in contact with them, as will deprive the metal of its compound. If a silicate of iron is melted, we do not precipitate iron by adding carbonate of soda, or caustic lime, to the fluid mass; this addition merely increases the fluidity of the *slag*, without producing any metal. But if we add sodium, the oxide of iron will be deprived of its oxygen, and form metal. Carbon has more affinity for *oxygen* than *metal*, in the high heat of a melted silicate. If, therefore, we add carbon to the melted silicate of iron, some iron is produced. In all cases, the metal requires a *slimy, glassy* substance coating, to protect it against the influence of oxygen, when exposed in small particles to that influence.

Almost all metals burn more readily than *carbon* —gold, the platina metals, and silver, in some meas-

ure, excepted. If, therefore, we desire to obtain a metal, we must produce a *slag*, which protects it, and at the same time admits of its coagulation. I would strongly recommend the founder to use as general flux (for copper foundings, particularly where large masses of copper have to be melted, prior to adding his tin and zinc), sal. enixum (the refuse from aqua-fortis), to be obtained at most of the chemical works, at a trifling cost. I know of nothing to equal it. This, with charcoal, surpasses every thing else.

TINNING CAST COPPER, OR BRASS.

CAST-IRON may be tinned by a solution of tin, as muriate of tin, mixed with an equal part of sal-ammoniac, if brushed over the metal, will highly further the operation of tinning; i. e., make a solution tin, by dissolving oxide of tin (tin putty) in potash ley—adding to the saturated solution some tin-shavings or filings. Make this hot as possible; place in your brass or copper, and they will be *tinned* in a few seconds.

The following table of experiments on the tenacities of metals, is given with the results, and the experimenters' names.

	In tons, 2240 lbs.	Experimenters
Cast copper,	8–¼	Sir J. Rennie.
Hammered copper,	15–0	"
Sheet copper,	21–0	Kingston.
Wire copper,	27–0	"
Wire platina,	17–0	Guyton.
Cast silver,	18–0	"
Wire "	17–0	"
Cast gold,	9–0	"
Wire "	14–0	"
Hard gun metal,	16–0	Sir J. Rennie.
Fine yellow brass,	8–0	"
Cast tin,	2–0	"
Wire tin,	3–0	"
Cast-iron, No. 1,	6 to 7¾	Hodgkinson.
Cast-iron, No. 2,	6 to 8	Hodgkinson.
Cast-iron, No. 3,*	6 to 9¾	Hodgkinson.

The above tests are on bars one inch square.

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* The strongest quality of cast-iron, is a Scotch iron known as the "Devon Hot Blast," No. 3. Its tenacity is 9¾ tons per square inch. Its resistance to compression is 65 do. The experiments of Major Wade,† on the gun-iron at West Point foundry, and at Boston, give to us results as high as 10 to 16 tons, throughout, and on small cast bars as high as 17 tons.

† Strength and other Properties of Metals for Cannon. 4to. Philadelphia: H. C. Baird. 1856.

ON REDUCING COPPER WITH WHITE ARSENIC.

In reducing copper scraps with white arsenic, for buttons, ornaments, candlesticks, clock dials, figures, &c., &c., to give them the color of silver the whole should be brought down under a flux of common salt. The metal is very highly poisonous, and should not in any case be used for cooking utensils. Arsenic being more fusible and brittle, is much used in shot factories, in the proportion of 1½ lbs. arsenic to 500 lbs. of lead for small shot, and 3 lbs. of arsenic to 500 lead for large shot.

TIN AND ZINC.

Tin and zinc will waste more than copper in re-melting metals. To prevent this as much as possible, a flux of potash and soda, freely mixed with charcoal, in the proportion of two ounces to the hundred pounds of metal, should be added immediately after the mass is melted, to prevent oxidation, and loss of strength and beauty. The quicker the metals are reduced under a good flux, and cast into work, the more perfect will be the crystallization and homogenity. If zinc is to be added after the crucible is taken from the fire (in casting brass work), it is best to introduce it in the form of yellow brass.

half an ounce of "gum mastic," in a phial by itself; one part spirits and half an ounce of "gum sandarach" in another phial; one part spirits and half an ounce of the whitest parts of "gum Benjamin." Then mix and temper to your mind. No rule can further instruct you, unless the quality of the gums and spirits could be ascertained. It would not be amiss to add a very small piece of "white rosin," or clear "Venice turpentine," in the mastic bottle; it will assist in giving a gloss. If your varnish should prove strong and thick, add clear spirits; if too hard, pour from the mastic bottle; if too soft, a little from the sandarach or Benjamin. When you have brought it to a proper temper and ready for use, warm the plate on a hot heater, and with a camel's hair brush dipped in the varnish, stroke it quickly over until no shades appear.

ON THE STRENGTH OF MATERIALS

BY C. A. LEE, C. E.

ALL solid bodies are proved to be possessed of certain general properties, among the most important of which is the capability of offering resistance to forces tending to change the relative position of their particles. It is this that it is proposed to discuss.

There are different hypotheses as to the ultimate arrangement of the particles of bodies, but for estimating their strength it is customary to suppose them to be made up of fibres running parallel to the length of the body—which fibres are more or less elastic, and capable of being extended or compressed within a certain limit, which is called the "limit of elasticity." The amount of compression or extension is directly proportional to the force applied, and to the length of the piece, and inversely proportional to the transverse section. It must be understood, however, that these changes of form are very minute, depending on the nature of the material in question. Moreover, the same force will produce equal extensions and compressions in the same piece. Suppose we take a bar

MATERIAL.	Weight of a cubic foot, in pounds.	Ultimate resistance to extension per square inch of section.	Ultimate resistance to compression per square inch of section.	Limit which should not be exceeded in practice—Extension.	Limit which should not be exceeded in practice.—Compression.
Ash (English)	47.5	17000	9000	1000	1000
Beech (do.)	43.8	11000	12000	"	"
Box	62.5	20000	12000	"	"
Elm	33.8	5800	10000	"	"
Fir (New England)	34.4	12000		"	"
Fir (Riga)	47.0	12600		"	"
Larch	33.8	7000	4000	"	"
Locust	59.5	20500		"	"
Oak (English)	50.0	12000	8000	"	"
Oak (Canadian)	54.5	12000	5000	"	"
Oak (Dantzic)	47.5	14500	7000	"	"
Pine (pitch)	41.2	10500	6700	"	"
Pine (red)	41.3	10000	7500	"	"
Teak	47.0	15000	12000	"	"
IRON.	**Weight of a cubic inch, in lbs**				
Bar 1 inch square (Welch)	0.281	58000	70000	10000	15000
Two inch round bar	"	59000	"	"	"
Russian 1 inch round bar	"	53000	"	"	"
Swedish 1 inch square bar	"	58000	"	"	"
American bar iron	"	48000	"	"	"
English cable iron	"	53000	"	"	"
" hammer hardened	"	63000	"	"	"
Iron Wire.					
½d inch diam. Philipsburg	"	75000		12500	
0.19 " " "	"	66000		11000	
0.156 " " "	"	80000		13300	
0.1 " " English	"	72000		12000	
Boiler Iron (American).					
Piled iron	"	56000	70000	9300	11700
Hammered plate	"	55000	"	9100	"
Puddled iron	"	51000	"	8500	"
Cast iron	0.26	18000	80000 to 150000	3000	13000 to 25000
Wrought Copper, in sheets	0.32	30000	100000	5000	16000
Cast Copper	0.317	17000	117000	3000	19500
Copper wire	0.32	60000		10000	
Cast Tin	0.263	4200	1000	700	170
Cast Zinc	0.248	8400		1400	

[TABLE CONTINUED.]

MATERIAL.	Weight of a cubic inch, in pounds.	Ultimate resistance to extension per square inch of section.	Ultimate resistance to compression per square inch of section.	Limit which should not be exceeded in practice.—Extension.	Limit which should not be exceeded in practice.—Compression.
Rolled Zinc	0.25	7000		1170	
Cast Lead	0.41	1700	483	300	80
Rolled Lead		1800		300	
Yellow Brass	0.282	16000	103000	2700	17000
Gun metal		32000		5300	
Granite	0.097		10000		1000
Sandstone	0.088	800	5000	80	500
Limestone (Magnesian)	0.115		5000		500
Oolites			2000		200
Limestone (Silicious)	0.114		5000		500
Hydraulic lime mortar	0.055	140	500	15	50
Hydraulic cement	0.056	234	700	25	70
Ordinary lime mortar (old)	0.058	70	500	6	50
Best quality Brick	0.069	280	2000	30	200
Inferior Brick	0.062	100	800	10	80

The preceding table has been prepared from the highest authorities—Morin, Poncelet, Claudel, Barlow, Hodgkinson, Franklin Institute, and others, and the utmost reliance may be placed upon it. It has been prepared especially for the *practical use* of American mechanics. The numbers in the fifth and sixth columns are those recommended by the most eminent engineers and practical men both in this country and Europe.

With regard to the absolute ultimate strength of materials, it is proper to state that they vary

very much for different specimens of the same material. This applies more especially to wood but also in some degree to all substances. It depends much on the state of the specimen. For instance, in the following table will be found the result of experiments made on short cylinders of timber, with flat ends, subjected to a compressive force. The cylinders were one inch in diameter and two inches in height. The results in the first column were obtained from timber moderately dry; those in the second column were obtained in like manner from similar specimens which were turned and kept in a warm place two months longer. A comparison of the two columns will show the great importance of having timber thoroughly seasoned in order to obtain its full strength.

DESCRIPTION OF WOOD.	Strength per square inch, in pounds.	
	Green.	Dry.
Ash	8683	9363
Beech	7700	19300
Birch	3200	11600
Oak (Quebec)	4230	6000
Oak (English)	6480	10000
Larch	3200	5560
Willow	2898	6128

With regard to the safe amount of strain it is

proper to charge materials with in constructions, the engineer will be guided in each particular case by his judgment. It is impossible to give rules for every case. If, for instance, a piece of timber is to occupy a position where the strain upon it is steady, and it is exposed to no abrasion or decay supposing it to be a fair sound specimen, it might be submitted safely to a strain as high as one sixth or one fifth of its ultimate strength. But, ordi narily, this would be too high. The French *mecaniciens*, Poncelet, Morin, Claudel, and others of the highest authority, have agreed upon certain limits to be used in practice for all kinds of materials and which will be given below. This limit for wood is one tenth the ultimate strength. This is the same ratio recommended by Haupt in his work on Bridges, and which he found to be perfectly successful in practice, as combining a judicious legree of strength with the least quantity of ma terial.

As the mean ultimate strength of wood may be rated at ten thousand pounds per square inch of section, both for compression and extension, we have for our practical limit, not to be exceeded in ordinary cases of construction, one thousand pounds per square inch. Where timber is exposed to

other than the legitimate strains due to its position in the structure to which it belongs, and which we will show how to calculate farther on, the engineer must of course use his judgment, unless these outside forces are such as to be calculated. The limits spoken of above, are, for wood, stone, and mortars, one tenth their ultimate resistance both for extension and compression, and one sixth for metals. As M. Poncelet has remarked, it would be more proper to determine these limits from the limits of elasticity of the several bodies, but experiments on this point have been made in but few instances.

ON THE STRENGTH OF IRON.—CAST-IRON.

THIS material, which has come to be used so extensively in the arts and in constructions, and whose uses are daily extending, has been made the subject of a great number of experiments. The most recent and reliable are those of Mr. E. Hodgkinson, the English experimenter. Those especially made by him on the strength of columns, both solid and hollow, and the most suitable forms for cast-iron beams to sustain a transverse strain, have supplied the engineer and architect with the most

valuable guide in using and adapting this metal to the various purposes of construction.

Resistance to Extension.--Experiments have been made on this point by Mr. Rennie and Captain Brown, of England, and under the direction of the Franklin Institute in this country, and also by Mr. Hodgkinson of England. The first named gentleman obtained for the ultimate tensile strength of cast-iron, from 14,000 to 18,000 pounds per square inch of cross section. The results obtained by Mr. Hodgkinson, also on English iron, both hot and cold-blast, was from 12,000 to 19,000 per square inch.

The experiments by the Franklin Institute on American cast-iron give for the mean tensile strength, 20,834 pounds per square inch. This material, however, on account of its brittleness, and comparatively low power of resistance to a strain of extension, is seldom ever submitted to it. It is much used in the shape of cast-iron beams, to resist a transverse strain, but this has been shown to be nothing more than a strain of compression on one part, and of extension on another part of the same piece. In large works, it would be much better to use a combination of cast and wrought-iron for resisting a transverse strain, the cast for compression and the wrought for extension.

Care must be taken however, that the different degrees of expansion of these two materials by heat produce no injurious effects. The limit of elasticity as assigned by Claudel, is $\frac{1}{1200}$th, and the force necessary to produce it 16,100 pounds per square inch. Some few remarks on the characteristics of cast-iron may not be out of place here. (They are mostly from the pen of Professor Mahan.) Cast-iron is divided into two distinct varieties, the white cast-iron and gray cast-iron. There are of course intermediate varieties, which partake more or less of the properties of these two, as they approach in appearance nearer the one or the other.

Gray cast-iron when of good quality is slightly malleable in a cold state, and will yield readily to the action of the file, when the hard outside scale caused by the chill in casting is removed. It is also sometimes termed soft gray cast-iron; it is softer and tougher than the white iron. On striking a sharp corner with the point of a hammer, an indentation will be produced, when in the other variety a piece would fly out. When broken, the surface of the fracture presents a granular structure, the color is gray, and the lustre is what is termed metallic, resembling small brilliant particles of lead strewed over the surface.

White cast-iron is very hard and brittle; when recently broken, the surface of the fracture presents a distinctly marked crystalline structure. The color is white, and lustre vitreous or glassy.

The following description, from Mr. Mallet's Report to the British Association for the Advancement of Science, comprises the different varieties:

"*Silvery.*—Least fusible, thickens rapidly, when fluid, by a spontaneous puddling; crystals vesicular often crystalline; incapable of being cut by chisel or file; ultimate cohesion a maximum; elastic range a minimum.

"*Micaceous.*—Very soft; a greasy feel; peculiar micaceous appearance, generally owing to excess of manganese; soils the fingers strongly; crystals large; runs very fluid; contraction large.

"*Mottled.*—Tough and hard; filed or cut with difficulty; crystals large and small mixed; sometimes runs thick; contraction in cooling a maximum.

"*Bright Gray.*—Toughness and hardness most suitable for working; ultimate cohesion and elastic range generally are balanced most advantageously crystals uniform, very minute.

"*Dull Gray.*—Less tough than the preceding; other characters alike; contraction in cooling a minimum

"*Dark Gray.*—Most fusible; remains long fluid, exudes graphite in cooling; soils the fingers; crystals large and lamellar; ultimate cohesion a minimum; and elastic range a maximum.

"The gray iron is most suitable where strength is required; and the white where hardness is the principal requisite."

The color and lustre presented by the surface of a recent fracture are the best indications of the quality of iron.

A uniform middling dark gray color and high metallic lustre are indications of the best and strongest. With the same color, but less lustre the iron will be found to be softer and weaker, and to crumble more readily. Iron without lustre, of a dark and mottled color, is the softest and weakest of the gray varieties.

"Iron of a light gray color, and high metallic lustre, is usually very hard and tenacious. As the color approaches to white, and the metallic lustre changes to vitreous, hardness and brittleness become more marked, until the extremes of a dull or grayish white color, and a very high vitreous lustre, are attained, which are the indications of the hardest and most brittle of the white variety.

"The strength of cast-iron varies with its density

and this element depends upon the temperature of the metal when drawn from the furnace, the rate of cooling, the head of metal under which the casting is made, and the bulk of the casting.

"The density of iron cast in vertical moulds increases according to Mallet's experiments, very rapidly from the top downward, to a depth of about four feet below the top; from this point to the bottom, the rate of increase is very nearly uniform.

"All other circumstances the same, the density decreases with the bulk of the casting; hence large, are proportionally weaker than small castings. From all these causes by which the strength of iron may be influenced, it is very difficult to judge of the quality of a casting by its external characters; in general, however, if the exterior presents a uniform appearance devoid of marked inequalities of surface, it will be an indication of uniform strength."

There has been considerable discussion with regard to the relative merits of hot-blast and cold blast iron. Messrs. Fairbairn and Hodgkinson have investigated the matter, and their conclusions are expressed in the following paragraph: "The ultimatum of our inquiries made in this way stands in the ratio of strength, 1000 for the cold-blast to 1024.8 for the hot-blast. The relative powers to

sustain impact are likewise in favor of the hot-blast, being in the ratio of 1000 to 1126.3."

The durability of cast-iron under exposure depends on different circumstances, the bulk of the casting, its homogeneity and density, &c. Mr. Mallet has made researches on this subject, and the following are the conclusions he arrived at:

"That the decay of iron when exposed to the action of water, is principally due to Voltaic agency, especially in tidal rivers, where there are strata of different densities, a Voltaic pile being thus formed of one solid body, and two fluid ones, making the corrosion much more rapid than where the water is homogeneous. Pure sea-water has much less action on iron than the water of harbors and docks, owing to the hydrosulphuric acid contained in the latter, and which comes from the mud at the bottom. In sea-water (pure) the rate of corrosion of pieces one inch thick, is four tenths of an inch for cast-iron, and six tenths for wrought-iron per century. In fresh water the corrosive action is much less than under any other circumstances of immersion, the coat of oxide formed on the outside not being dissolved and washed away as in sea-water, but remaining as a kind of protection. In hot sea-water, the corrosion is most rapid of any

other circumstances. Iron, chill-cast, corrodes more rapidly than when cast in green sand, by reason of the want of homogeneity of the metal, thus forming Voltaic couples of different densities. When soft and hard cast-iron are brought together under water, the soft is corroded much more rapidly than when by itself, while the hard suffers much less; castings made in dry sand are more durable in water than those made in green sand. From one eighth to one fourth of an inch on the outside of castings, is termed the hard crust. When this is removed, the iron corrodes much more rapidly. The chief point in making castings to be exposed to this agent, is to have them as homogeneous as possible, and of as great density."

Mr. Mallet concludes with the following very judicious remarks: "The engineer of observant habit will soon have perceived, that in exposed works of iron, equality of section or scantling, in all parts sustaining equal strain, is far from insuring equal passive power of permanent resistance, unless, in addition to a general allowance for loss of substance by corrosion, this latter element be so provided for, that it shall be equally balanced over the whole structure; or, if not, shall be compelled to confine itself to portions of the general structure

which may lose substance without impairing its stability."

COMPOSITION FOR SILVERING BRASS.

TAKE silver, or gold lace, half an ounce; add thereto one ounce of double refined aqua fortis; put them in an earthen pot, and place them over a gentle fire till all be dissolved, which will happen in about five minutes; then take it off and mix it in a pint of clear water, after which, pour it into another clean vessel to free it from grit or sediment and then add a spoonful of salt, and the green water will immediately let go the silver particles, which will form themselves into a white curd. Then pour off the water and throw it away, for it is of no further use. The white curd must then be mixed with two ounces of salt of tartar, half an ounce of whiting, and a large spoonful of salt, more or less, according as you find it for strength. Mix it well up together, and it is ready for use.

TO SILVER BRASS.

HAVING well cleared the brass from all scratches (otherwise it will spoil its appearance), rub it over with a piece of an old beaver hat and rotten-stone to clear it from all greasiness; then rub it with salt and water with your hand; then take a little of the before-mentioned composition on your finger, and rub it over where the salt has touched, and it will adhere to the brass, and appear as well as silver. After which, wash and steep it in plenty of clear cold water, to kill the aqua fortis which remained in the composition; and when dried with a clean hot rag, it is then ready to be varnished with the white lacquer.

RESISTANCE TO COMPRESSION.

THE best authority on this point is Mr. Hodgkinson, whose experiments were very full and varied. The trials were mostly on small columns with circular bases. The resistance was found constant for a height less than once and a half the diameter of the base, from this to a height equal to three times the base; the resistance was less than before, but

still remained constant; and for any height greater than this, the resistance decreased with the height. When the piece was higher than three times the base, the rupture generally took place by bending. The pieces submitted to experiment generally yielded by an oblique fracture, the upper part sliding off on the lower. The angle made by the plane of the fracture, with the axis of the solid, was constant, and equal to about 55°.

The strength was found to be in direct proportion to the area of the cross section. The measure therefore, of the resistance offered by a solid to rupture, either by compression or extension, is that force which will rupture a sectional area of the solid represented by unity. The following are the results obtained by Mr. Hodgkinson. The mean of the experiments on hot-blast iron gave, for crushing weight, 121,685 lbs. per square inch; cold-blast iron gave a mean of 125,400 lbs. per square inch. These were on short prisms, whose cross section was a circle. When the section was a square, or other regular figure, the resistance was decreased to 100,600 lbs. per square inch.

Table from Mr. Hodgkinson's Experiments.

DESCRIPTION OF METAL.	Compressive Force per square inch, in pounds.	Tensile Force per square inch, in pounds.
Devon iron, No. 3, hot-blast.....	145,435	21,907
Buffery iron, No. 1, hot-blast.....	86,397	13,434
Do. " No. 1, cold-blast.....	93,385	17,466
Do. " No. 2, hot-blast.....	82,734	16,676
Do. " " cold-blast.....	81,770	18,855
Carron iron, " hot-blast.	108,540	13,505
Do. " " cold-blast.....	106,375	16,683
Do. " No. 3, hot-blast.....	133,440	17,755
Do. " " cold-blast.....	115,442	14,200

Resistance to a Transverse strain.—The resistance of cast-iron to a transverse strain, is a subject of the highest importance to the engineer and architect. Indeed, to prove this, it is only necessary to point to the daily extending uses of this material in almost every possible shape, and it is well known that cast-iron is seldom, if ever, submitted to any other than a transverse strain, as in cast-iron beams, girders, &c., and a strain of compression, as in columns, which will be investigated farther on.

The theory of the transverse strain has been fully investigated; and great numbers of experiments have also been made on this point, so that among mechanics the matter is considered as sufficiently settled.

The remarks below apply to other materials, as well as to cast-iron.

Let A B be a body to which a force, P, is applied, in a direction perpendicular to the direction of the fibres. Supposing the force to be sufficient to bend the body, as in the figure, the fibres *a b*, on

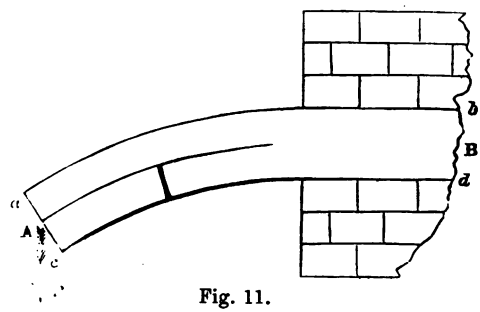

Fig. 11.

the upper side, will be extended, while those, *c a*, on the lower side, will suffer a strain of compression. This can be made evident; for, by increasing the weight P, until a fracture takes place, the rupture will be found to commence on the convex side, thereby proving that the fibres on that side have been most extended; and if some of the fibres on the convex side be separated by cutting them through transversely, it will be found that a smaller force than P will suffice to produce the rupture.

If, on the contrary, the fibres on the concave side, *c d*, be cut through transversely to a depth, *m n*

corresponding to about half the depth of the piece, and a slip of hard material like a sheet of iron be interposed, so as to just fill the place cut out, it will be found, on subjecting it again to the force P that the thin plate will be strongly retained by a pressure tending to compress it, while the strength of the solid will not be altered—the rupture commencing under the same strain, and in the same place as before. As we proceed from the convex toward the concave side of the solid, the extension of the fibres will gradually become less, until at a point at or near the centre of the piece, the length of the fibres will be found to undergo no variation. Beyond this distance, the fibres will be found to be more and more compressed, until we arrive at the concave side, where the compression will be at its maximum. The position of the fibres, whose form is not altered by the flexure, and represented by the line *e f*, is called the neutral axis. Its position varies for different substances, but for practical purposes may be considered to coincide with the centre of gravity of a transverse section of the solid.

The fibres, whose lengths are not altered, are contained before the flexture in a plane perpendicular to the direction of the pressure, and which,

of course, contains the neutral axis, as one of its elements. After the flexure, these fibres form a cylindrical surface, whose elements are parallel to the same plane.

Moreover, the fibres, at equal distances above and below this plane, undergo equal extensions and compressions.

In order to investigate the circumstances of a body submitted to a transverse strain, it is necessary to obtain the moment of the acting force, with reference to the points of support, and establish an equation between this and what is called the "moment of elasticity," when the deflection of the body is in question, and the moment of rupture, when rupture is the point. The investigation is conducted by the aid of the higher analysis, and would be of no use to the practical engineer. It is therefore omitted—all the results, however, being given in a form to be easily understood. These remarks apply to other materials, wood, &c., as well as to cast-iron.

The experiments of Mr. Hodgkinson on cast iron beams, the strength of best form for, &c. are the latest and most reliable authority on this point.

The following are the results of one of his ex-

periments on bars of cold-blast iron five feet long; distance between supports, four feet six inches; the weight being applied at the middle of the bar:

Rectangular Bar 1 inch deep, 1 inch broad.			Rectangular Bar 2 inches deep, 1 inch broad.			Rectangular Bar 3 inches deep, 1 inch broad.		
Weight in pounds.	Defl'ct'n in inches.	Set in inches.	Weight in pounds.	Defl'ct'n in inches.	Set in inches.	Weight in pounds.	Defl'ct'n in inches.	Set in inches.
16	.033		1082	.091	.003	4936	.110	.013
30	.062		1343	.111	.006	5867	.130	.017
56	.120	.002	1605	.138	.008	6798	.153	.020
112	.240	.007	1836	.164	.010	7730	.179	.025
168	.370	.014	2126	.190	.012	8662	.195	.030
224	.510	.028	2388	.220	.015	9593	.219	.034
280	.649	.041	2649	.250	.019	10525	.250	.042
336	.798	.061	2910	.281	.026	10588	Broke.	
392	.953	.084	3172	.310	.031			
448	1.120	.120	3433	.345	.037			
504	1.310	.170	3694	.378	.046			
514			3825	Broke.				
518	Broke.							
Ultimate deflection, 1.36.			Ultimate deflection, .395.			Ultimate deflection, 0.252.		

STATIC PRESSURE OF WATER UNDER DIFFERENT HEADS.

A CONVENIENT and easily remembered method for approximating to the pressure of water, is to allow one half pound pressure per square inch for each foot of head. The pressure at any point being directly as the perpendicular depth below the level

of the surface, this simple rule affords a ready method of ascertaining its amount with an accuracy sufficiently close for ordinary purposes. That it is not strictly correct, however, may be readily perceived; and having occasion, recently, to calculate with tolerable exactness the pressure corresponding to several heads between ten and one hundred feet, I present the following Table for the convenience of others, having enlarged it by the addition of several numbers outside of the limits named above. The temperature of the water is assumed at 59° Fahrenheit; the density, from the presence of salts and other foreign matters, is assumed at 1.000,149, distilled water being 1.000,000. This density, corresponding with the investigations of Briagarand on the water of the Garronne, and with that of Brisson on the Seine, I have assumed as the density of ordinary fresh water. An allowance should perhaps be made for the increase of density due to the compression under great heads, but too slight to be of any practical importance.

Recent experiments on this point indicate a compression about $\frac{4\frac{1}{2}}{10000}$ of its bulk, under a pressure of one atmosphere, or 33.90 feet head.

A pipe of cast-iron 15 inches diameter and $\frac{1}{4}$ of an inch thick, will sustain a head of water of six

hundred feet. One of oak, two inches thick, and of the same diameter, will sustain a head of one hundred and eighty feet.

Head in feet.	Pressure, in pounds, per square inch.
1	.43
2	.86
3	1.30
4	1.73
5	2.16
10	4.33
15	6.50
20	8.66
25	10.83
30	12.
35	15.16
40	17.33
45	19.50
50	21.66
55	23.83
60	25.90
65	28.06
70	30.55
75	32.72
80	34.66
85	36.83
90	38.90
95	41.07
100	43.33
125	54.17
150	65.
175	76.05
200	86.67
300	130.01
400	173.34
500	216.68
600	259.02
700	305.55
800	346.69
900	389.03
1000	433.37
1500	650.05
2000	866.74
3000	1300.11
4000	1733.48
5000	2166.88
6000	2600.22
7000	3033.59
8000	3466.96
9000	3900.33
10000	4333.70

By paying strict attention to the above Table,

much loss and inconvenience will be saved, particularly to plumbers, &c., in laying down pipes of the required strength according to the pressure, saving bursting, taking up, and laying down others, to say nothing of the annoyance of tearing up pavements, highways, &c., through the want of a proper knowledge of the static pressure in all cases per square inch.

DIRECTIONS FOR PREPARING AND FITTING BABBITT'S ANTI-ATTRITION METAL.

MELT 4 pounds of copper, add by degrees 12 pounds best quality of Banca tin, 8 pounds regulus of antimony, and 12 pounds more of tin while the composition is in a melted state.

After the copper is melted and 4 or 5 pounds of tin have been added, the heat should be reduced to a dull red, to prevent oxidation; then add the remainder of the metal as above. In melting the composition, it is better to keep a small quantity of powdered charcoal on the surface of the metal. The above composition is called *Hardening*. For lining the boxes, take one pound of this *Hardening* and melt it with two pounds of Banca tin, which produces the lining metal for use. Thus, the pro

portions for *Lining Metal* are 4 pounds of copper, 8 pounds of regulus of antimony, and 96 pounds of Banca tin.

The article to be *lined*, having been cast with a recess for the *lining*, is to be nicely fitted to a *former*, which is made the same shape as the bearing. Drill a hole in the article for the reception of the metal, say one half or three fourths of an inch, according to the size of it. Coat over the part not to be tinned with a clay wash; wet the part to be tinned with alcohol, and sprinkle on it powdered *sal ammoniac;* heat it till a fume arises from the sal ammoniac, and then immerse it in melted Banca tin, care being taken not to heat it so that it will oxidize.

After the article is tinned, should it have a dark color, sprinkle a little sal ammoniac on it, which will make it of a bright silver color, and cool it gradually in water. Then take the *former*, to which the article has been fitted, and coat it over with a thin clay wash, and warm it so that it will be perfectly dry; heat the article until the tin begins to melt, lay it on the *former*, and pour in the metal, which should not be so hot as to oxidize through—the drilled hole giving it a head, so that as it shrinks

it will fill up. After it is sufficiently cool remove the *former*.

P. S.—A shorter method may be adopted when the work is light enough to handle quickly, viz.:—When the article is prepared for tinning, it may be immersed in the lining metal instead of the tin, brushed lightly in order to remove the sal ammoniac from the surface, placed immediately on the *former*, and lined at the same heating.

SOLDERING FLUID FOR SOFT SOLDER.

To two fluid ounces of muriatic acid add small pieces of zinc until bubbles cease to rise; add half a teaspoonful of sal ammoniac, and two fluid ounces of water.

P. S.—By the application of this, iron or steel may be soldered *without being previously tinned*.

ALLOY OF THE STANDARD MEASURE USED BY GOVERNMENT.

576 Parts of copper,
59 " tin,
48 " brass (yellow, 22 cop. to 1 of zinc).

TUTENAG.

8 parts of copper, 5 parts of zinc, and 3 parts of nickel.

EXPANSION METAL.

9 parts of lead, 2 parts of antimony, and 1 part bismuth.

BRONZING GUN BARRELS.

First make the barrels smooth and bright with emery; after which clean carefully with lime to remove all grease; then apply the following mixture with a clean sponge or rag: To a quart of soft water, add one ounce and a half of spirits of wine, one ounce and a half tincture of steel, half an ounce of corrosive sublimate, one ounce and a half of sweet spirits of nitre, one ounce of blue vitrol, and three quarters of an ounce of nitric acid. The barrels are then to be exposed to the air for twenty-four hours, after which rub with a steel scratch-brush until the rust is entirely removed; then again apply the mixture, and in a few hours repeat the scratch brushing. Continue the operation for four or five days; then wash the barrels with plenty of hot water, and while hot, finish with a leather and a little beeswax and turpentine. This will give a fine and glossy finish.

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